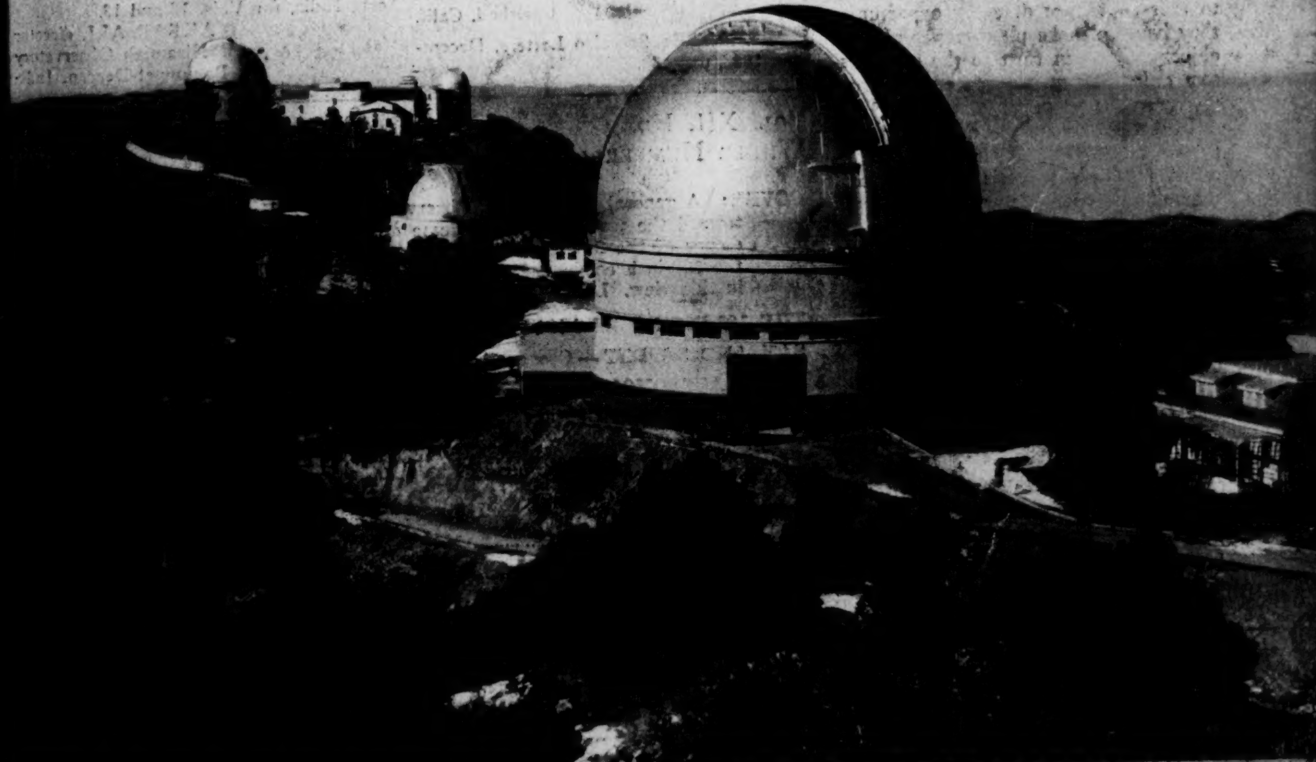
Sky and TELESCOPE



Lick Observatory today

ol. XII, No. 4
BRUARY, 1953
ole Number 136

In This Issue:

Hale Reflector Photographs the Moon and Planets

On December 15th, some of the first photographs of the moon and planets made with the 200-inch telescope were released. Because of public interest in these objects, during the past two years the telescope has been used to photograph our bright neighbors whenever time permitted. The pictures released were immediately published in many newspapers and magazines.

"While they are not the best plates the instrument can make, they are the best so far obtained," said Dr. Milton L. Humason, staff member and secretary of Mount Wilson and Palomar Observatories. "Clearer, sharper pictures may be made sometime with better atmospheric conditions, but ideal conditions are so rare that years may elapse before better pictures can be made with the 200-inch telescope."

The Hale reflector was expressly designed for and is engaged in a systematic study of very distant nebulae, clusters, and galaxies. Since excellent seeing is rare, Palomar astronomers try to take advantage of every opportunity they have to make photographs of such objects; they can turn to the solar system only if they can spare time from their regular programs.

In discussing the new Palomar photographs, Dr. Seth B. Nicholson, discoverer of four of Jupiter's satellites, said that although the pictures show known details on a larger scale, they do not reveal more than can be seen visually with even smaller instruments. Photography of the moon and planets is limited chiefly by turbulence and other conditions of the earth's atmosphere that disturb and distort the image.

The new 200-inch photographs may be obtained from the California Institute of Technology Bookstore, 1201 East California St., Pasadena 4, Calif. In sizes 8 x 10, they are 75 cents each; 16 x 20, $5.00; lantern slides, 4 x 3¼, $1.50. Add 75 cents per order to cover postage and packing. With their catalogue numbers, the new pictures are:

SP-14 Moon, region of Clavius
SP-15 Moon, region of Copernicus
SP-16 Mars, in blue and red light
SP-17 Mars, two views in blue light
SP-18 Jupiter, in blue light
SP-19 Jupiter, in blue light
SP-20 Jupiter, in blue light, showing large red spot
SP-21 Jupiter, in blue light, showing large red spot; satellite Ganymede and shadow (above)
SP-22 Jupiter, in red light; satellite Ganymede and shadow (above)
SP-23 Saturn, in blue light.

Sky and TELESCOPE

LETTERS

Sir:

In your June, 1952, issue you published a few paragraphs about my article in **Scientific Monthly** on Crater Elegante (News Notes, page 191). After several months of delay I have received Air Force pictures of Crater Elegante that prove beyond a doubt that it is not of impact origin. It is much too unsymmetrical in shape to be a meteor crater, but it is so big that when one stands on the rim, it appears to be perfectly round. Apparently it is just a volcanic caldera which happens to have a number of other features resembling an impact crater.

ALLAN O. KELLY
P. O. Box 542
Carlsbad, Calif.

ED. NOTE: See also Letters, December, 1952, page 30.

Sir:

Nizamiah Observatory, Hyderabad, wants to dispose of the surplus stock of its publications in 13 volumes comprising the Hyderabad Astrographic Catalogue, zones +35° to +40°, −16° to −21°, and −20° to −24°, free of charge to observatories, institutions, and persons interested in them. The recipients will, however, be asked to pay the full cost of packing and postage. Requisitions for the above publications should reach the following until the end of September, 1953:

Neill and Co., Ltd., 212 Causewayside, Edinburgh, Scotland, for Vols. 1 to 8.

Percy Lund, Humphries and Co., Ltd., 12 Bedford Square, London W. C. 1, England, for Vols. 9 to 11.

Nizamiah Observatory, Begumpet-Deccan, India, for Vols. 12 and 13.

AKBAR ALI, director
Nizamiah Observatory
Begumpet-Deccan, India

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COVER: A general view of Lick Observatory on Mt. Hamilton, California, looking toward the west. The huge dome of the new 120-inch reflector dwarfs the domes of the 20-inch, 36-inch, and 12-inch instruments. The blockhouse for the 120-inch coude spectrograph projects from the left side of the building in this view. Lick Observatory photograph. (See page 91.)

BACK COVER: A region of the Milky Way in Monoceros, Orion, and Gemini, reproduced from Plate 35 of the Ross-Calvert **Atlas of the Northern Milky Way**, published by the University of Chicago Press. (See In Focus.)

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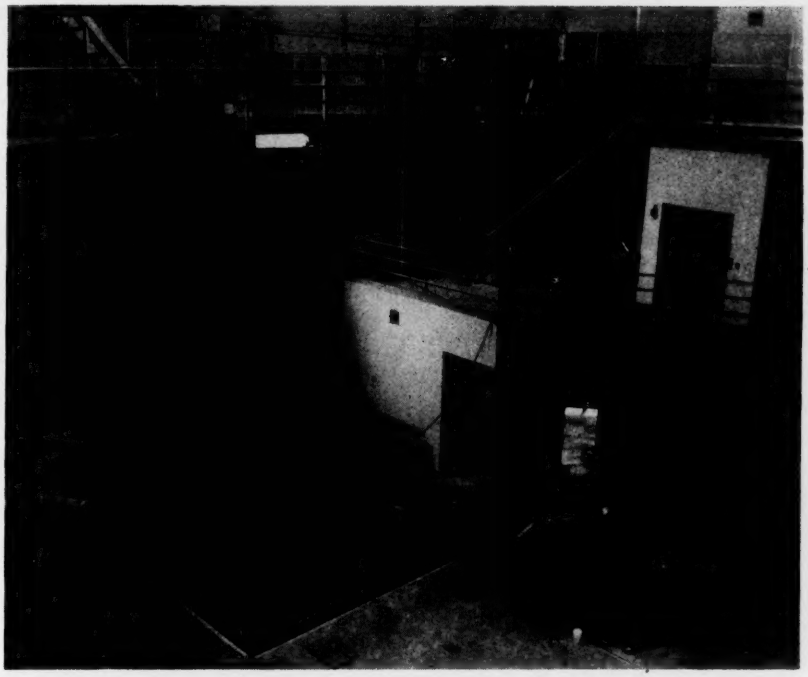


The four levels of the new building that will house the 120-inch telescope of Lick Observatory. From bottom to top are the basement floor, observing floor, mezzanine, and gallery. All pictures with this article are Lick Observatory photographs by Fred Chappell.

The 120-inch Telescope

OLIN J. EGGEN, *Lick Observatory*

IN 1875 James Lick, an ex-piano maker from Stumpstown, Pa., and California's first multimillionaire, set aside $700,000 with the provision that it be used to construct the "most powerful telescope in the world" for the University of California. The Lick Observatory's 36-inch refractor fulfilled Lick's provision for 11 years and then was superseded by the 40-inch refractor of the Yerkes Observatory. Later, when it was learned that 40 inches was the practical limit for refracting telescopes, emphasis was shifted to the reflecting type of instrument. Larger and larger mirrors were built until, in 1948, the 200-inch at Palomar Mountain was completed. Since the 200-inch telescope with accessories cost more than $7,000,000, and the price of large telescopes increases roughly as the cube of their linear size, larger instruments will probably be long in coming.

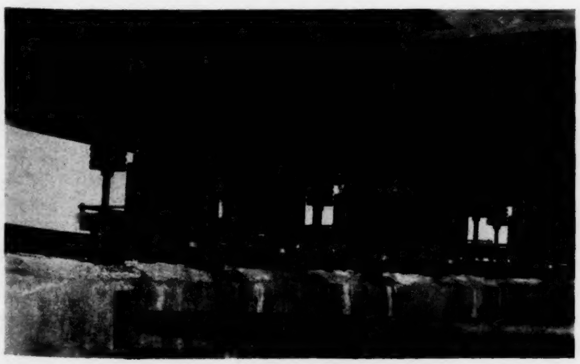
On March 13, 1946, Governor Warren of California signed a legislative appropriation bill that eventually provided nearly $2,000,000 for a large reflecting telescope on Mt. Hamilton. The construction of the building to house the new instrument was started in 1950 and completed two years later, in March, 1952, by the firm of Carrico and Gautier, general contractors of San Francisco.

The dome is 97 feet in diameter and 94 feet high — these are the diameter and one half the height, respectively, of the dome of the nation's capitol — and it contains everything the astronomer needs for his comfort and for his work. The basement floor is used for the optical shop and three sleeping rooms. The built-in optical shop permits the 120-inch mirror to be ground and polished "on the spot." For testing the mirror when it is completed, the shop includes a concrete-walled tunnel, 11 feet wide and 11 feet high, that extends, underground, 73 feet beyond the outer wall of the building. The basement bedrooms are windowless, insulated, and air-conditioned so that the astronomers can sleep unmolested by daylight, heat, and noise.

The main or observing floor contains offices, a lounge and kitchenette, instrument storage rooms, electronics laboratory, photographic darkrooms, and a glassed-in enclosure from which visitors can view the telescope without interfering with its operation. These facilities are around the perimeter of the building, and they surround the observing floor where the telescope is mounted. The darkrooms are air-conditioned, and a 45-cubic-foot freezer-refrigerator is located near the observing floor for storing photographic plates.

Above the main floor there is a mezzanine and a gallery. The first of these provides access to the mounting of the telescope, which rises nearly 20 feet above the observing floor, and the second is a catwalk that is attached to the rotating portion of the dome.

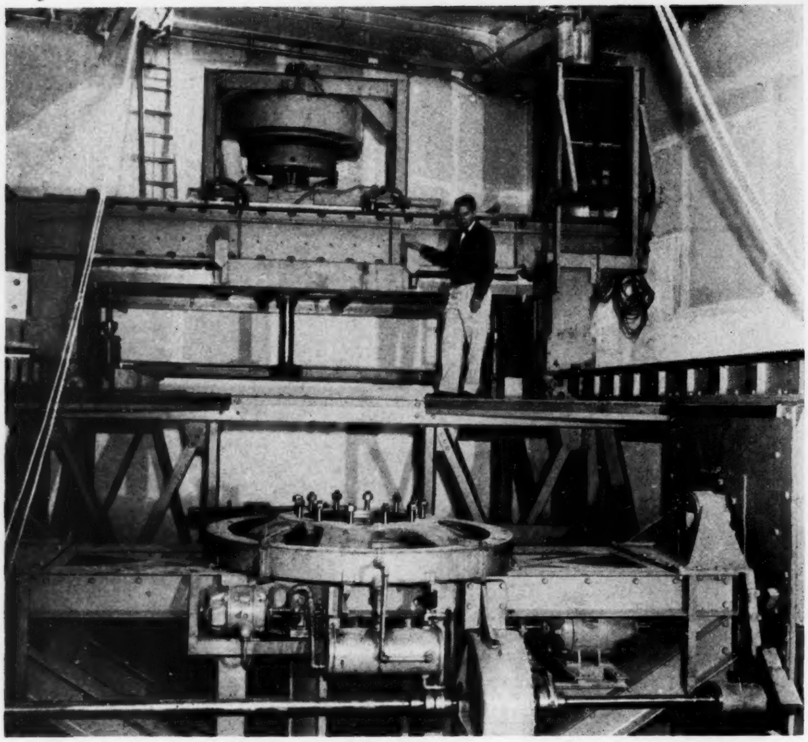
The 260-ton dome rotates on a single rail, and is supported by springs on 30 2-wheeled trucks that move so smoothly that no vibration is transmitted to the telescope. It is driven by three motors, each of 1½ horsepower. The outside wall of the dome is composed of lap-welded steel plates, a quarter of an inch thick. The inner wall is made of embossed aluminum panels, each backed by seven layers of aluminum foil. A three-foot gap is left between the inner and outer walls. As the warm air rises through this space, cool air enters from below; thus, the heating of the building by the sun's rays during the day is prevented. To carry the astronomer and small instruments from the basement floor to the gallery there is a special elevator, and high above the observing floor a 15-ton hoist in the top of the dome lifts heavier equipment.



A closeup of the trucks that carry the weight of the 260-ton dome of the new building.

Within the dome, with entirely separate foundations, the telescope base is built on 20-inch-diameter pilings that extend to a depth of 20 or more feet into the fractured sandstone of which Mt. Hamilton is made. Nearly 4,000 sacks of cement were used in liquid grout to consolidate the rock around the pilings, and to provide a foundation of sufficient stability for the complex steel pier of the telescope.

The mounting for the telescope, which is being constructed by the Judson Pa-



The grinding machine for the 120-inch mirror, with Dr. N. U. Mayall standing in front of the beam that travels from the back to the front of the picture.

cific-Murphy Corporation, Oakland, Calif., is of the long-fork type. It consists of a cylinder so supported as to rotate on bearings, with the trunnions of the telescope tube carried by two projecting arms. The 23-foot hollow fork will "grab" the telescope tube a quarter of its length up from the mirror end.

The 4-ton "waffle-back" mirror is to be mounted in a 35-ton, 50-foot tube. The whole 129-ton combination of fork, mirror, and tube will ride on a film of oil, only a few thousandths of an inch thick, and will be driven by a 1/12-horsepower motor.

The astronomer will literally be part of the telescope, for he will ride in an observation cell, unofficially referred to as the "squirrel cage," located in the upper end of the tube. This elliptical cell, which will rotate with the motion of the telescope to keep the astronomer always "upright," will cut off only 11 per cent of the light that would otherwise fall on the mirror. The observer will be lifted to the cage by an elevator that travels up the side of the dome in the shutter opening.

The 120-inch glass disk was cast in 1933 as a trial run for the 200-inch mirror, and it was intended to be used in testing the larger disk in the final stages of polishing and figuring. Before it could be put to such use, however, a better method of testing was developed and the 120-inch disk became surplus. It was retrieved from storage in 1949 and purchased by the Lick Observatory for $50,000, much less than the estimated cost of a new mirror. It will be ground, polished, figured, and aluminized. As an uncertain estimate, the telescope may be in operation in about three years. It is fortunate that the 120-inch telescope could be constructed from designs that incorporate many ideas developed, tested, and shared by the planners and makers of its 200-inch predecessor.

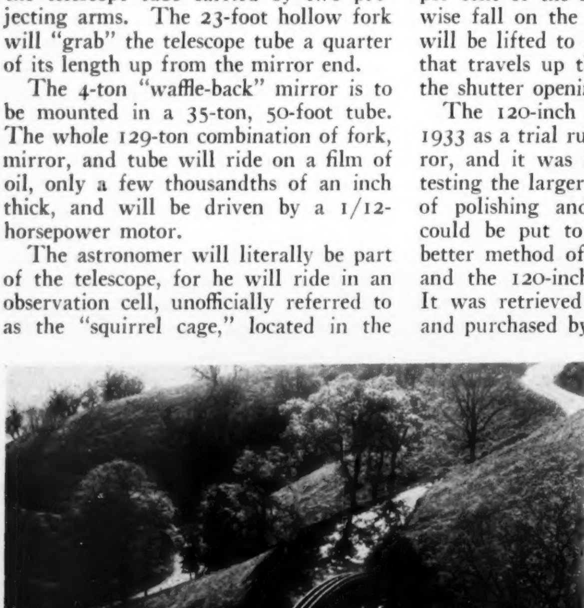
The beam of the 120-inch grinding machine, shown in the accompanying picture, carries a motor-driven spindle which attaches to the grinding tool. The spindle is at the middle of the beam in the picture; it moves along the beam to give motion in the left-right co-ordinate. In the original design, the two motions were combined electronically, to drive the tool over the disk, but the arrangement was found to be unsatisfactory because of too much inertia in the system. Also, it was unsafe and tended to throw the tool off the machine whenever a relay stuck.

This beam, however, will be left on the machine, since the spindle also has a vertical motion that will be used to lift the tool off the disk. For grinding, the tool will be guided with a standard Draper arm. This had not arrived at the end of the year, but it is expected momentarily, and as soon as it comes grinding of the 120-inch disk will begin. In the meantime, the auxiliary optics are being ground on the smaller, old 60-inch, machine.

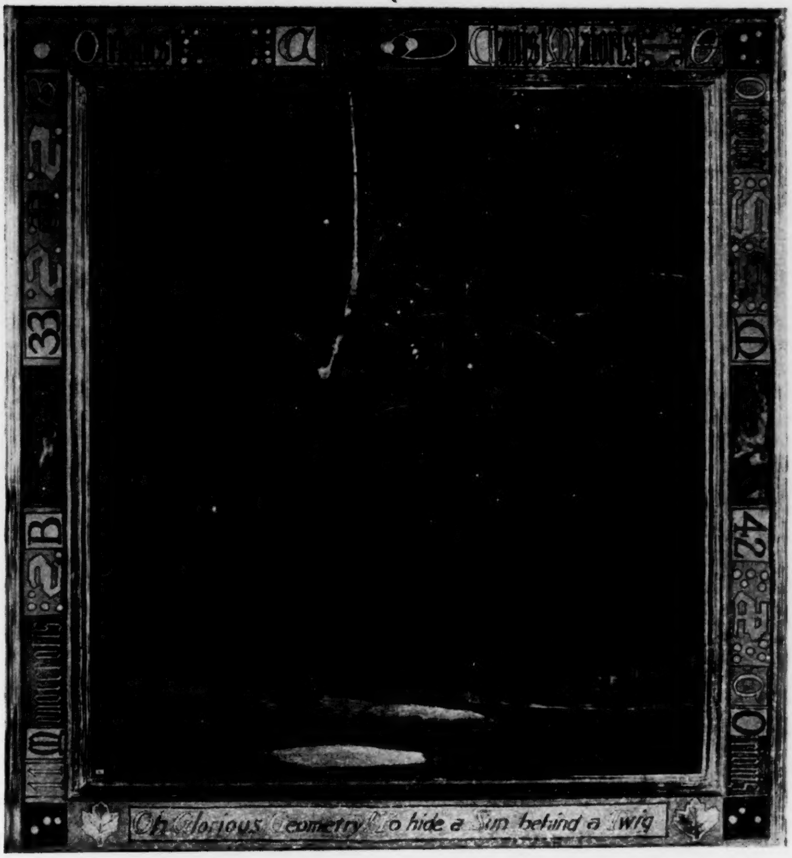
RELATIVITY SHIFT CONFIRMED

Dr. G. Van Biesbroeck, of Yerkes Observatory, has successfully completed his observations and measurements of the bending of starlight past the sun during the eclipse of February 25, 1952. The National Geographic Society has announced his results as confirming the prediction of the theory of relativity that the gravitational bending of starlight just missing the edge of the sun would be 1.75 seconds of arc.

The actual observations of stars around the eclipsed sun, corrected for differences in their distances from the sun's edge, showed an average displacement of 1.70 seconds. Dr. Van Biesbroeck measured his plates with a precision measuring machine at the Yale University Observatory. The eclipse plates were compared with a second set of photographs made at night at the same site near Khartoum, Anglo-Egyptian Sudan, on August 29th, six months and four days after the eclipse. These comparison plates were taken at the precise moment that the same stars had the same relative positions in the sky as during the eclipse, to eliminate corrections for atmospheric refraction effects.



A typical section of the winding road leading to the summit of Mt. Hamilton, where the 120-inch telescope will be located (see the front cover). The truck is carrying sections of the arch girders for the dome. It was stalled for several hours, holding up all traffic on the road.



In the early evening skies of northern winters, Orion and his faithful followers, Canis Major and Canis Minor, are high in the southern sky. This is a reproduction of a painting by the late D. Owen Stephens, "Orion and Sycamore," in which "Sah" and "Sopdet" may be easily identified.

SAH AND SOPDET

BY GEORGE A. DAVIS, JR.

STRANGE as it may seem, the names of the stars and constellations which have come down to us from the ancient Egyptians can be counted on the fingers of one hand. Even the name of Canopus, the second brightest star in the sky, which must have always been a familiar object to them, is utterly unknown. Fortunately, however, we know the names of the constellation of Orion and of the star Sirius, which was so important to the Egyptians in connection with the yearly inundation of the Nile.

Orion was called *Sah* and Sirius was called *Sopdet*. The meanings of these names, however, have never, to my knowledge, been published in any language. Perhaps the present is as good a time as any to remedy this omission, particularly in the realm of astronomy, by a brief discussion.

The earliest reference to *Sah* which has come to my attention is that inscribed on the walls and corridors of the Pyramid of Unas at Sakkara, the last king of the vth Dynasty, who reigned over Egypt from about 2655 to 2625 B.C. The inscription, which is contained in lines 496 to 525, is a very famous one, and undoubtedly recalls acts of cannibalism on the part of the Egyptians of predynastic times. It is stated that the deceased king has made his way into heaven amidst the terror of the gods, whom he hunts and kills. He then cooks and eats them, thus magically absorbing all their strength and power. The inscription then goes on to say: "Unas is a god, the eldest of the firstborn. He is given the power of the Great Sekhem, the constellation of *Sah,* the father of the gods. Thousands revert to him; hundreds are offered to him. He renews his risings in the sky, for he is the Seben crown (or "Great One") as lord of the horizon."

In the *Book of the Dead,* CLXXII, 36 (from the Papyrus of Nebseni), we read: "Thou (the deceased) risest up like *Sah,* and the goddess Nut stretcheth out her hands unto thee. *Sah,* the son of Ra and Nut, who gave birth to the gods." And in LXIX, 5 (from the Papyrus of Mes-em-neter): "I am *Sah,* who approaches his domain, and who journeyeth along before the stars of heaven, which is the belly of my mother Nut." In I, 17, we read (from the Turin Papyrus): "May I rise like a god endowed with life; may I give forth light like the company of the gods who dwell in heaven; may I see the Sektet boat of the sacred *Sah* passing forth over the sky." And in the Pyramid of Pepi I, 187 (a king of the VIth Dynasty), Orion is spoken of as "*Sah* of the long stride and extended step, Chief of the Land of the South."

Sopdet is, of course, also mentioned in the *Pyramid Texts* and in the *Book of the Dead,* and is the celestial manifestation and abode of Isis, the greatest goddess of Egypt from the earliest to the latest dynasties.

In the *Book of the Dead,* CLXXIV, 8 (from the Papyrus of Mut-hetep), we find the star *Sopdet* referred to as "the foremost one who bringeth along the celestial path of Ra day by day." In the Pyramid of Pepi I, 390, the deceased king is said to be "the brother of the Moon, the child of the star *Sopdet,*" and it is also said that "he revolves in heaven like *Sah* and *Sopdet,* and rises in his place like a star." From the same Pyramid, 100, we are told that the star *Sopdet* guides the deceased king "over the beautiful roads in heaven into the Field of Reeds." And in the Pyramid of Teta, 348 (the first king of the VIth Dynasty), the deceased's soul is strong and "provided like the star *Sopdet.*" Again in Pepi I, 690, it is said that "Ra hath conceived Pepi; Pepi is of the seed of Ra and *Sopdet,* in thy name of Heru-khent-khu ("the sweetest smelling of those who smell sweet"), the star which saileth over the Great Green Sea."

The hieroglyphic symbols for *Sah* contain the five-pointed star and a peculiar character which represents the toes of the person who is being described. The symbols for *Sopdet* include the five-pointed star and a thorn, the latter being the universal symbol for the star from the earliest times.

Sah means the "Approaching One," and is derived from the verb meaning "to approach" or "draw near to," and, perhaps originally, "to touch with the toe." The word *sah-ta,* "to touch the land," is a common expression used of boats coming to shore.

Sopdet means "to be pointed"; but why the star, as the goddess Isis, should be called the "Pointed One" is unknown, if we assume that the name is purely indigenous to Egypt. If, however, Semitic or other foreign influence is tentatively assumed, it is interesting to recall the names of the star, or the constellation itself, among the Sumerians, Babylonians, Assyrians, Hindus, and Chinese, where a pointed weapon is indicated.

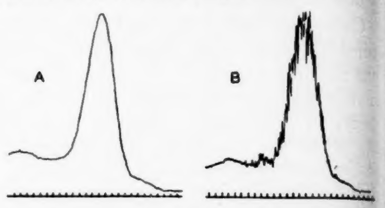
Radio Astronomy at Jodrell Bank--I

By A. C. B. Lovell, *Jodrell Bank Experimental Station, University of Manchester*

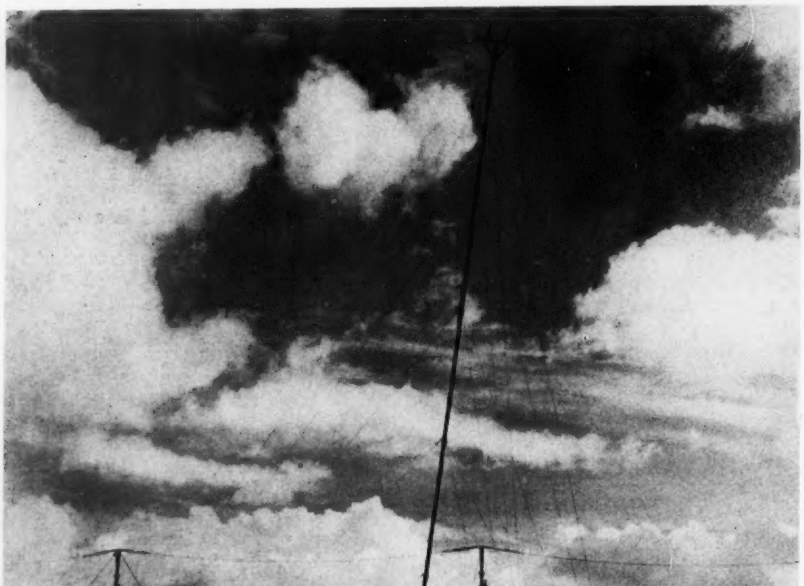
There are two main centers for research in radio astronomy in Great Britain. One, under the leadership of Martin Ryle, is at the Cavendish Laboratory in Cambridge. The other belongs to the University of Manchester, although it is at a considerable distance from the town, at Jodrell Bank in Cheshire. The Cambridge work is primarily concerned with the investigation of radio waves from the sun and outer space. The solar radio emissions occupy only a small part of the work at Jodrell Bank, where the main emphasis is on radio waves from space and on observations in which radio waves are transmitted from the earth in order to study the astronomy and physics of meteors.

The problem of resolving power has been approached differently at the two centers. In Cambridge, Ryle uses radio interferometers in which two aerial systems are separated by many wave lengths. This arrangement produces a reception pattern of fine lobes, as described by Otto Struve in *Sky and Telescope* for January, 1950. At Jodrell Bank, resolving power has been improved by increasing the physical dimensions of the aerial system. For several years a large fixed radio telescope with an aperture of 220 feet has been in use there. It was primarily the success of this fixed instrument which led to the proposals for a great steerable radio telescope, and as the construction of this latter instrument has now been commenced, an account of the work at Jodrell Bank may be of interest.

The fixed radio telescope. Some idea of the construction of the 220-foot-aperture radio telescope may be gained from the photograph. The paraboloidal bowl is formed of wire stretched between 24 perimeter posts, and secured to the ground at three other points on each radial run. The dipole aerial system at the focus is carried on a steel tower 124 feet above ground. The radio telescope is normally directed toward the zenith, but the beam can be displaced up to ± 14 degrees from the vertical by tilting the tower. Thus it is possible to explore the radio emissions from the strip of sky about 28 degrees wide moving through the zenith at the latitude of Jodrell Bank (53° north). The operating wave length of the radio telescope is controlled by the size of the aerial at the focus. So far it has been used mostly on a wave length of two meters, in which case the beam width for reception is about ± 1 degree to half-power points and ± 2 degrees to zero.



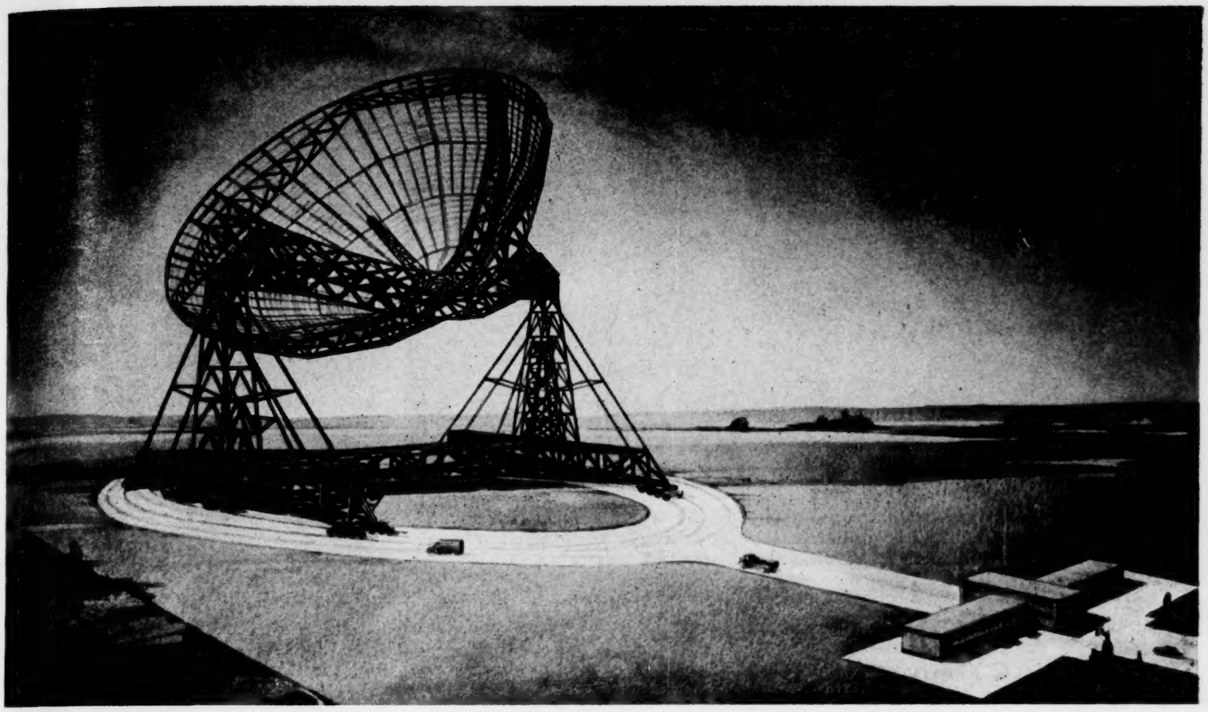
The appearance of the radio star in Cygnus as it transits the beam of the 220-foot radio telescope. The vertical axis represents the signal strength, and the horizontal axis represents time or right ascension (two minutes to each division). The diameter of the radio star is very small compared with the aerial beam width, and thus the extension of the record in right ascension is due to the width of the beam. Record A was obtained when the scintillations were absent; they were prominent during record B.



The 220-foot-aperture radio telescope at Jodrell Bank, showing the dipole aerial and the thin wires making up the paraboloid. When this photograph was taken, the beam displacement was about seven degrees from the zenith, and the operating wave length was two meters. Crown copyright reserved.

The resolving power of the radio telescopes used by Jansky and Reber in their pioneer work was limited, and it appeared that the radio emissions from space were arising in a diffuse source — which Reber believed to be the interstellar gas — distributed along the galactic plane with a maximum concentration toward the galactic center. Subsequent work confirmed the general nature of this distribution, but in 1948 Bolton and Stanley in Sydney, and Ryle and Smith in Cambridge, using radio interferometers, discovered that at least some of the radiation was originating in localized sources which are now referred to as radio stars [or discrete sources].

These radio stars are prominent features of the records obtained with the Jodrell Bank radio telescope. The accompanying diagram shows the appearance of the second most intense source



The artist's drawing of the great 250-foot steerable radio telescope now being built at Jodrell Bank. The instrument is to be rotated on the railway track by 100-horsepower motors. The elevation movement is around the horizontal axis 180 feet above ground, and also requires 100-horsepower motors. These drive through 28-foot racks obtained from the dismantled battleship "Royal Sovereign." Crown copyright reserved.

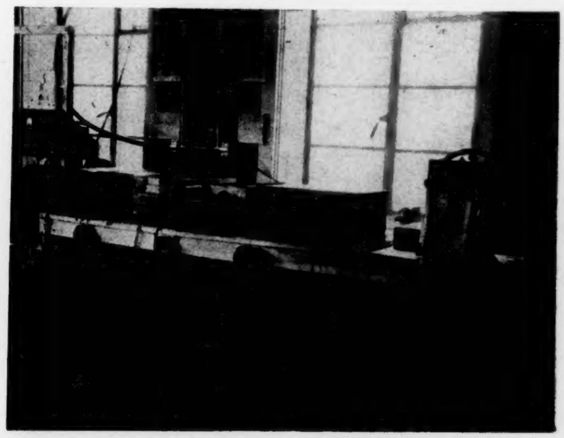
in the sky and the effect of the disturbed conditions in the F region of the ionosphere which cause the twinkling of the radio stars. Hanbury Brown and Hazard have now made a detailed study of the distribution of the radio sources that are within the field of view of this telescope. The strongest radio stars show a marked concentration in the galactic plane, whereas the weaker ones appear to have a distribution nearly isotropic.

One interesting feature of their work is the identification of a radio star in the position of Tycho Brahe's supernova (1572), of which there are no visible remnants. In the original work on the radio stars, Bolton and Stanley found that one was coincident with the Crab nebula — the supernova of 1054. Unfortunately, the only other supernova known in the local galaxy (Kepler's 1604), is outside the field of view of the 220-foot radio telescope; even so this new result seems to place beyond reasonable doubt that supernovae generate intense radio emissions. Otherwise, the Jodrell Bank work confirms the result that the radio stars do not seem to be related to any prominent visible objects. The survey of the radiation which is unresolved into radio stars confirms that the distribution is closely related to the intensity of starlight, and a good deal of information has been obtained about the obscured parts of the galaxy, particularly the region in Cygnus.

Perhaps the most spectacular results with the radio telescope are those of Hanbury Brown on the extragalactic radio emissions. In 1950, he was able to demonstrate that the Andromeda nebula (M31) emitted radio waves and that in this respect it was similar to the Milky Way system. Many more galaxies have now been surveyed, and the radio/light intensity relationship has been established for individual extragalactic nebulae and for extragalactic clusters.

The angular diameter of the radio stars. The failure to identify the majority of the radio stars with any particular class of visible celestial object has led to a concentrated effort to find out more about the actual diameters of the radio sources. The resolving power of a radio interferometer depends on the separation of its aerials. In those first used in Sydney and Cambridge the signals in the two aerials were compared before rectification, and this placed a limit on the extent of the aerial separation. Consequently, the radio stars could not be fully resolved and it was known only that their angular diameters must be less than five or six minutes of arc.

Hanbury Brown has recently designed a new type of interferometer in which the signals from the two aerials are compared after rectification and in which no limit is placed on the possible separation of the aerials. Jennison and Das Gupta, working with this interferometer



Some of the electronic apparatus used by Hanbury Brown and Hazard in their work on the galactic and extragalactic radio emissions. The thick cable at the left goes to the aerial at the focus of the radio telescope. The recording chart on the right shows a gap caused by the intense source in Cassiopeia passing through the beam of the radio telescope and deflecting the pen off scale.

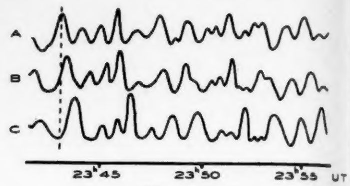
The appearance of the site of the 250-foot radio telescope in early November, 1952. The piles of reinforced concrete are being sunk into the ground. About 60 had been completed when the photograph was taken.

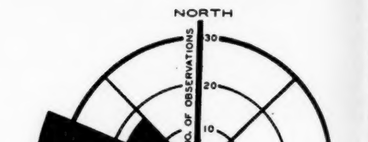
during the summer of 1952, succeeded in determining the angular diameter of the radio star in Cassiopeia as about three minutes of arc, and of that in Cygnus as an elongated object about three minutes by 45 seconds of arc. These sizes are only a little less than the limits of resolution of the original Sydney and Cambridge interferometers, and later it was learned that improvements in these had led to simultaneous measurements with similar results. The elucidation of the size of the radio source in Cassiopeia is of particular interest, since it agrees very well with the area occupied by the gaseous nebulosity in this region, recently studied by Baade and Minkowski with the 200-inch telescope, and which is now believed to be responsible for the radio emission.

The scintillation of the radio stars. The intensity of the signals from the radio stars often shows fluctuations. This was at first thought to be caused by variations in the strength of the emissions from the source. In 1949 a series of experiments was made, jointly with the group at the Cavendish Laboratory, in which the Cygnus and Cassiopeia sources were observed simultaneously with identical equipments. The records of the fluctuations obtained at the two stations were quite dissimilar, thus indicating that they could not arise in the source. Subsequently, the investigations were pursued both at Jodrell Bank and in Cambridge.

It has now been established that the fluctuations arise when the radio waves pass through the upper F region of the ionosphere at an altitude of about 400 kilometers, and that they are due to diffraction by electron clouds several kilometers in extent. These electron clouds move at high velocities through the ionosphere. By comparing the fluctuation records on three suitably spaced receivers it is possible to measure the velocity and direction of these F-region winds.

The cause of the F-region irregularities is not yet known. They appear to be essentially a nighttime phenomenon and to be closely associated with the occurrence of the "diffuse" or "spread F" sporadic phenomena, well known in the pulse investigations of the F region. Ryle has suggested that the irregularities may be caused by the accretion of interstellar dust; another suggestion is that since they occur when the ionization is weak, they are due to the breaking up, or granulation, of the F region. At the latitude of Jodrell Bank, the radiations from Cygnus and Cassiopeia at lower culmination pass through the auroral zone. Little and Maxwell have shown that under these conditions fluctuations are nearly always present and must be attributed to the very disturbed ionospheric conditions in those regions.

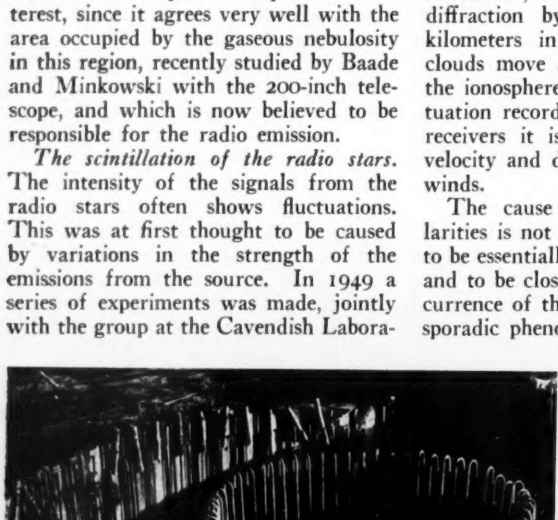




When the scintillations of the radio stars are observed on three receivers arranged triangularly at spacings of about four kilometers, time displacements can be measured, as in the records at A, B, and C, and from these the F-region wind directions and velocities can be calculated. An example is given in the histogram, which shows the F-region wind directions for evening observations made in May and June, 1951. The winds were blowing toward the directions indicated and ranged in velocity up to 800 kilometers an hour.

The new steerable radio telescope. The successful work with the large fixed radio telescope made it clear that an instrument of this size which could be directed to any part of the sky would be of inestimable value. It was also evident that the construction of such a steerable radio telescope would involve a considerable engineering enterprise. After several years of work, sufficient plans were available early in 1951 for financial proposals to be made, and in the spring of 1952 it was announced that the cost, amounting to nearly a million dollars, would be shared equally by the Nuffield Foundation and the Government Department of Scientific and Industrial Research. The foundations for this great structure are now being laid at Jodrell Bank. In order to support the railway track on which the instrument will rotate, 160 reinforced con-

(Continued on page 114)



The central thrust block of the 250-foot radio telescope mounting as it appeared in early November, 1952. The reinforcing bars of the central block, on which the entire instrument pivots, can be seen in position.

G Forces and Weight in Space Travel*

By Fritz Haber, *Dept. of Space Medicine, Air Force School of Aviation Medicine*

IN THE YEAR 1492, mankind was still struggling with the idea that the earth was not a flat disk, but a globe. Columbus was not the one to discover this fact, but was one of its most ingenious and successful promoters, as his results show. The story goes that in his efforts to obtain support in his plans, he was occasionally confronted with the argument that nobody could live on the other side of the globe because he would just "fall off." A few centuries later Isaac Newton could theoretically disprove such embarrassing accidents; however, Columbus tried it long before and proved that the same firm stand existed on the soil of America as it did on the soil of Spain.

It has never been reported how Columbus explained this fact and how he cleared up the confusion as to what direction was up and what was down, on the other side of the globe. He rightly believed that his weight kept him from falling off the globe and certainly was glad that it was of the same amount and direction as that on the other side of the earth. He therefore had no reason to doubt the constancy of weight. It took a few more centuries, however, to produce the occasions where such strange things as the variation of weight could happen.

It is common belief that weight is constant at all times, on all occasions. The National Bureau of Standards is the authority on this topic and sees to it that "a pound is always a pound." Since aviation and rocketry have made the variation of weight a daily experience, it became apparent that a revision of the concept of weight was necessary.

We should no longer adhere to the opinion that weight is a quality of a body, such as its color, its shape, or its smell. In daily life if you want to know how heavy a certain piece of meat is, you weigh it on a scale. That seems very simple. However, it can become quite complicated, especially if that particular piece of meat happens to be full of life and is your energetic youngster. Such small fry likes to bounce up and down, making it almost impossible to read the weight on the scale. If you cannot convince your youngster to keep absolutely quiet, you walk away without knowing his weight.

This story shows the condition necessary in measuring the weight of a body. Scale and body must be kept quiet or, in more scientific terms, they must not be accelerated. This rule, although known for centuries, was clarified and explained by Newton, the founder of classical mechanics. Newton stated that any acceleration of a body requires a force acting on the body. He further formulated that this force is equal to the product of the acceleration times the mass of the body, whereby acceleration is the rate of change of speed in amount or direction. Another Newtonian law establishes the relation between action and reaction, that is, each active force has its reactive counterpart of the same size but opposite direction. According to this law, a force acting on a body and accelerating it has a counterpart which is commonly referred to as the force of inertia. If a force of inertia is produced by an acceleration of the same amount as the acceleration of a body in the gravitational field of the earth, then one speaks of a force of inertia of one **g**. This is the reason the forces of inertia are sometimes called **g** forces.

G forces can be measured in the same manner as weight, that is, by employing scales — and that was exactly what you did when you put your bouncing youngster on the scale. He was accelerating himself up and down, thus producing forces of inertia of variable amount, which showed on the dial. No wonder you could not find out what his weight was.

A youngster jumping up and down on a scale is certainly not a scientific setup. We therefore rely a little on our imagination and think of a scale with a piece of metal on it. Scanning the dial, we find a weight of, say, 100 pounds. If we transfer scale and metal to a point way out in space where no gravitational field exists, and then accelerate scale and metal at the same rate as it would be accelerated in the gravitational field of the earth, then we could read a force of inertia of 100 pounds. But, what makes you think that this time the 100 pounds are forces of inertia? If you and the entire setup were enclosed in a box with no means of detecting motion or acceleration, how then could you differentiate between weight and force of inertia? The indicator on your dial shows 100 pounds and "that's it." Both indications could be called weight, or both could be called forces of inertia as well.

Physicists have pondered over these phenomena, and believe that a body has two different kinds of masses: the gravitational mass, a quantity which displays itself as the attraction between two bodies— and the inert mass, a quantity which becomes apparent as a force of inertia during an acceleration. A careful physicist always make a distinction between those two attributes of a body, despite the fact that there is no experiment known which gives evidence that the two kinds are in any way different from each other.

This differentiation between the gravitational mass and the inert mass is the reason for the differentiation between weight and force of inertia. Normally, weight is identified with the force of attraction between gravitational masses, while force of inertia is considered to be different from weight.

Now, you might ask if this differentiation is necessary and justified, since no experiment and no means exist to separate one from the other. Why should we make a discrimination which cannot be enforced? You certainly will agree to merging the two concepts into one and giving it a proper name. I see no reason why we should not call it weight. But, we should make one special definition. We call the weight obtained on the surface of the earth under unaccelerated conditions the "normal weight" of a body. Under any other conditions, forces of inertia are added to or subtracted from the normal weight, resulting in an amount of weight that can be anything from zero to many times the normal weight.

From the foregoing considerations, we can see that the weight of a body is really not a constant but is a result of its state of acceleration. For the same reasons it is not a quality of the body. You have all experienced this either when going around a corner in a car, riding an elevator, or sitting in a train that is brought to a sudden stop. In all these instances, your body weight was different from your normal weight.

What really is the weight of a body and how can it be determined? It is this question that we have been asked many times in the Department of Space Medicine. There are many possible and correct answers, but one — in our opinion — is the clearest: The weight of a body is equal to the force of its support, and is independent of the force gravity. This explanation is especially suited for analyzing the weight of an entire system, such as an airplane, a rocket or a spaceship. The only fact to be considered is the supporting force, which includes all external forces acting on the body. The sum of all these forces is then equal to the weight of the body. An airplane in the air is supported by the aerodynamical lift and derives its weight from this lift. The pilot can vary this lift and make it three or four times as great as the normal weight of the airplane. The craft then weighs three or four times its normal weight. In all cases of weightlessness the identification of weight with support becomes exceptionally clear if a body is left without any support whatsoever; then we can state immediately that the body is without weight. This is true everywhere, independent of the existence of a gravitational field, as can be proven by a simple experiment.

Take a bottle partly filled with water, seal it, shake and mix the contents; the air and water inside the bottle will separate very quickly, just as soon as you stop shaking the bottle, due to the difference in weight of water and air. In a state of weightlessness, however, this separation does not take place because the water and air then do not have a different weight, that is, they both have no weight. You can render the bottle weightless by depriving it of its support — by allowing it to fall. During the fall you can then see that the water and air do not separate but stay mixed. This is proof that the state of weightlessness is possible even in a gravitational field. It is also proof that the weight is equal to the supporting force.

All that I have said so far to a great extent is part of space travel because rockets and spaceships are designed to vary the force of their support and there-

***From a talk given at the Second Symposium on Space Travel at the Hayden Planetarium, American Museum of Natural History, October 13, 1952.**

fore their weight. We could reduce the idea of a spaceship to the statement that a spaceship must be capable of varying and controlling its support in any desired fashion.

Visualize, if you will, a spaceship at the moment of takeoff. The rocket engine has been started and is developing a certain amount of thrust. It is imperative that this thrust be greater than the normal weight of the ship, otherwise it would not be lifted off the ground. A thrust somewhat greater than the normal weight lifts the ship in an accelerated motion. The thrust of a rocket engine can be considered constant, while the total mass of the rocket decreases due to the fuel burned and discharged during the operational period of the rocket engine. A constant propulsive force acting on a rocket of decreasing mass produces an ever-increasing acceleration of this rocket. This results in ever-increasing forces of inertia, that is, increasing weight for everything within the rocket during the period of takeoff.

A rocket engineer is anxious to see his ship go fast because the economy of rocket propulsion is improved by a high speed. In order to obtain high speed as quickly as possible, it is necessary to perform the takeoff with a high acceleration, that is, with great weight of the crew. However, there is a limit to this, a human limit, that is. The human body in a prone position can tolerate an 11-fold increase of its weight for two to three minutes, and in supine position a 14-fold increase for the same time. Breathing becomes very difficult due to the tremendous weight of the parts of the chest, which must be moved for the purpose of respiration. The values quoted were obtained in experiments with a constant acceleration. In a rocket takeoff, however, the acceleration and likewise the weight are not constant but increase toward the end of the propulsion period. To tolerate an increased weight is always a very unpleasant experience, but to know that it will become worse as time goes on adds a psychological factor. Engineer and doctor should co-operate on this point in order to achieve the highest performance of man and machine.

After the rocket has attained the desired speed, its engine is cut off. At this time the thrust and the support have become zero. From the foregoing discussion we know that no support is the equivalent of no weight and therefore the rocket and everything in it are without weight as soon as the engine ceases operating. The speed, the shape of the trajectory, or any gravitational field plays no role.

I would like to point out here that for a body without support it is not the trajectory which determines weightlessness. It has often been said that an artificial satellite must move around the earth in a circle with a certain speed in order to be weightless. This, however, is not true. Speed and shape of the trajectory should be properly chosen in order to avoid contact with the atmosphere or escape from the earth. Weightlessness has nothing to do with these considerations.

How does it feel to be weightless? Everyone at some time has been weightless; after jumping off a chair or a diving

(Continued on page 114)

NEWS NOTES

By Dorrit Hoffleit

"NORTHERN LIGHTS" IN THE LABORATORY

Within the past few years, Dr. A. B. Meinel, of Yerkes Observatory, has had remarkable success in observing and interpreting the spectrum of the aurora borealis. Now *Physics Today* in its November issue reports his further successes. With C. Y. Fan, Dr. Meinel used the kevatron at the University of Chicago's Institute for Nuclear Studies in an attempt to confirm his theory of the aurora by laboratory experiments. These scientists bombarded air at low pressures with alpha particles and protons and found a striking similarity to the aurora, indicating that it is indeed produced when the upper atmosphere is bombarded by such particles from outer space. It is inferred that part of the auroral effect is produced when the electrons knocked off of atmospheric atoms are captured by protons.

BRIDGES BETWEEN GALAXIES

Dr. Fritz Zwicky, Palomar Observatory, has long been a believer in the existence of material in intergalactic space. Efforts with the 18-inch Schmidt telescope to discover such material proved fruitless because of the small scale of the photographs. Now, with the 48-inch Schmidt, he has had marked success. There are galaxies, separated by many times their own diameters, found to be connected by filaments of luminous matter. A striking example is a triple system consisting of the two bright galaxies IC3481 and IC3483 with an unnamed smaller galaxy between them but nearer the brighter. The two bright galaxies are separated by at least 72,000 light-years, the minimum length of their bright curved connecting filament.

It is suggested that the three galaxies are revolving around or oscillating through one another with periods of the order of 100 million years. During their close encounters material may be ejected forming the connecting filaments. Some of the matter, in the cases of widely separated galaxies, may well be ejected into intergalactic space and lost to the parent systems.

A consequence of such discoveries of intergalactic matter in greater abundance than was heretofore believed is that the universe may have a higher average density than has been assumed, perhaps as high as 10^{-26} grams per cubic centimeter, instead of the previously accepted 10^{-28} to 10^{-30}.

IN THE CURRENT JOURNALS

WHAT I DON'T KNOW ABOUT FLYING SAUCERS, by Otto Struve, **Griffith Observer**, December, 1952. "As an astronomer, I am concerned only with the question of whether any of these objects can be explained in terms of known astronomical objects or in terms of some unknown apparition of extraterrestrial origin."

TIME AND ITS MEASUREMENT, by G. M. Clemence, **Leaflet** Nos. 283 and 284, Astronomical Society of the Pacific, November and December, 1952. "What we, as scientists, know about time itself is very little indeed. We can say much more about the measurement of it."

NATHANIEL BOWDITCH AND HIS WORK, by Paul E. Wylie, **Navigation,** September, 1952. "The facts of Bowditch's life are well known. . . . But what sort of book was the **American Practical Navigator**? . . . Although little in the current edition is from the pages of the original book, still, Nathaniel Bowditch would be proud, I think, to find his name on the title page of the current volume."

LYMAN-ALPHA OBSERVED IN SOLAR RADIATION

Early V-2 rockets procured solar spectra to wave lengths slightly shorter than 2600 angstroms. Now, Naval Research Laboratory scientists Byram, Chubb, Friedman, and Lichtman have sent photon counters aloft to measure intensities in the region from 1180 to 1300 angstroms. This includes the ultraviolet hydrogen Lyman-alpha line at 1216 angstroms. In three Aerobee flights during May, 1952, the line was first observed at heights of about 74 kilometers (sun's altitude 18 to 20 degrees). Measurements were also made near 2050 angstroms, and X-rays were detected above 90 kilometers, confirming a 1951 observation of a high energy limit to the solar spectrum near 7 angstroms.

ANOTHER COMET MRKOS

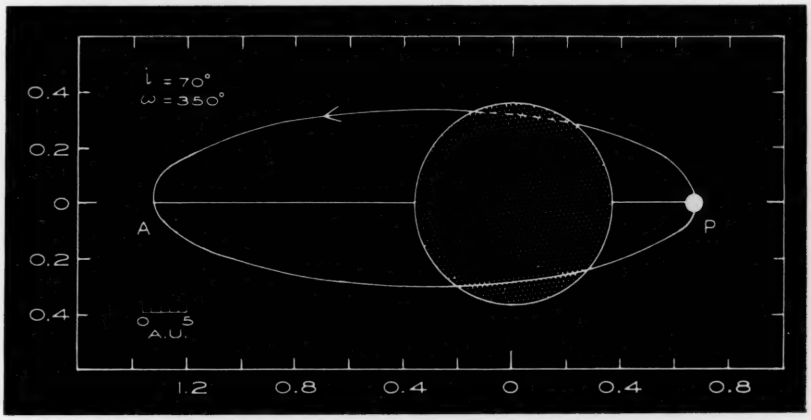
At the Skalnate Pleso Observatory in Czechoslovakia, A. Mrkos has discovered his second comet for 1952, which is called 1952f. On December 9th, the new object was in the position $13^h\ 27^m.0$, $-11°\ 50'$, and of the 10th magnitude. It was observed at Lick Observatory, by Elizabeth Roemer, to be of the 9th magnitude on December 13th and 15th, and Dr. L. E. Cunningham, Leuschner Observatory, computed an approximate ephemeris. The last two predicted positions were for January 13.0, $16^h\ 56^m.0$, $-64°\ 31'$, and January 18.0, $18^h\ 54^m.4$, $-67°\ 43'$. Thus, the comet has moved far into the southern part of the sky.

The first comet found by Mrkos last year was 1952c. He discovered it in May, when it was of the 10th magnitude.

The Coming Eclipse of Epsilon Aurigae

By Otto Struve, *Leuschner Observatory, University of California*

EPSILON AURIGAE is an eclipsing binary, and its period of 27.1 years is the longest on record.* Its most recent eclipse started in the middle of 1928 and lasted until the middle of 1930. The normal apparent magnitude is about 3.4. The partial phases of the eclipse last about half a year each, and the total phase, with an apparent magnitude of 4.2, lasts about one year.



The orbit of Epsilon Aurigae, projected on the plane of the sky, showing the path of the smaller bright star with reference to the invisible large one, as well as the dimensions of the components relative to the orbit size. The inclination of the orbital plane to the plane of the sky is assumed to be 70°, and the line of apsides, from the periastron at P to the apastron at A, nearly coincides with the line of nodes. The vertical and horizontal scales are on the basis of unity for the system's semimajor axis, and astronomical units are shown by the small insert. From a joint paper by G. P. Kuiper, O. Struve, and B. Stroemgren, courtesy the "Astrophysical Journal."

The period is very well determined. The variable was discovered by the German pastor, Fritsch, at Quedlinburg in 1821, but no light curve was determined until 1848, when Schmidt at Athens and Argelander at Bonn obtained good visual observations of the minimum, and especially of the rise toward normal light. Since then there have been three eclipses, in 1875, 1902, and 1929, all well observed with the best available methods. A careful discussion of the entire material was made, in 1936, by Miss M. Güssow at Berlin-Babelsberg, and her prediction for the middle of the next eclipse, 1929 April 30 + 9,890 days, should be accurate to about a day or two. This would lead us to expect the beginning of the partial eclipse in August, 1955.

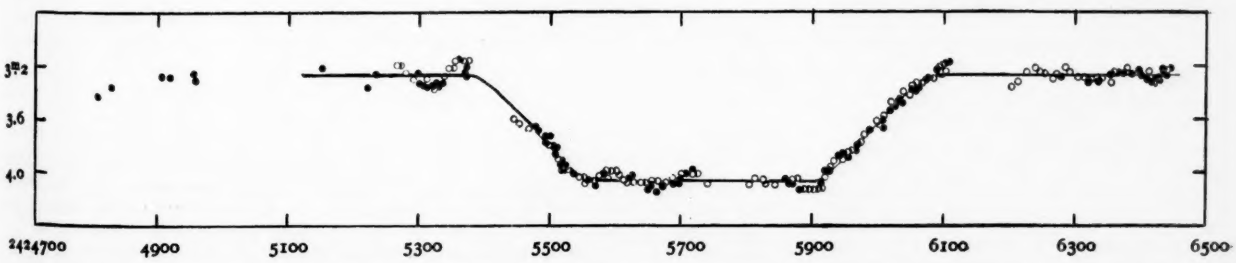
But Epsilon Aurigae is a supergiant of exceptional properties. One component of the binary, the star whose light we normally observe, and whose radiation is reduced by 0.8 magnitude during total eclipse, is about 300 times the diameter of our sun. This makes it equal in size to the largest stars measured with the great Michelson-type interferometer — Betelgeuse, 400 times the diameter of the sun; Mira Ceti, 500 times the sun; and Antares, 300 times the sun.

The other component of Epsilon Aurigae, normally invisible, is about 10 times larger yet, with a diameter about 3,000 times that of the sun. This object is so large that the solar system almost as far out as Uranus could be placed inside of it! If it is really a star, it is the largest known to us at the present time. The next largest is the red component of VV Cephei, about 2,400 times the sun's diameter.

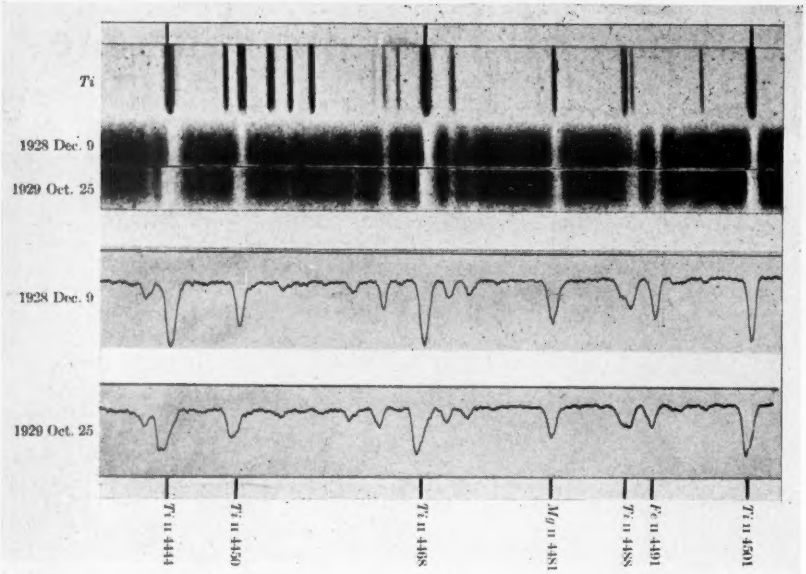
These enormous bodies are almost perfect vacuums, equivalent to those produced by the best diffusion pumps in our physical laboratories. The larger component of Epsilon Aurigae has an average density about one-billionth that of the sun, or about one one-millionth of air at normal atmospheric pressure! Since the density cannot be uniform, it must be even smaller near the edge which we would call the photosphere, if this were an ordinary star. But the invisible component is not ordinary in any sense, and we can almost certainly apply to it a word first used by Gaposchkin in another connection, and describe it as an "edgeless" star.

The spectrographic observations in 1928-30 indicated that about 2½ years before the photometric eclipse started the spectral absorption lines began to show a small shift in wave length, which was probably coupled with a slight asymmetry of the line profiles, rendering them steeper on their red edges than on their violet edges. The asymmetry of the lines gradually increased and be-

*A faint star in the southern hemisphere, H. D. 306989, was recently announced by the Rev. D. J. K. O'Connell, of the Riverview Observatory (he is now director of the Vatican Observatory), as having an even longer period, but an exhaustive study by S. Gaposchkin, with the help of the large collection of Harvard Observatory photographs, left considerable doubt concerning the character of its light variation; and J. Sahade has shown, at Cordoba, that the spectrum of this star is quite peculiar. Hence, for the time being we do not know whether H.D. 306989 is really an eclipsing variable. Perhaps it is an irregular variable like Z Andromedae or P Cygni.



Individual measurements of the brightness of Epsilon Aurigae according to M. Güssow (black circles) and J. Stebbins and C. M. Huffer (open circles), showing the 1928-1930 eclipse. A correction of —0.17 magnitude has been made to the latter observations to bring them into the same magnitude system as the Güssow observations. The horizontal scale is in Julian days. Reproduced from the publications of the Berlin-Babelsberg Observatory.



The spectrum of Epsilon Aurigae on December 9, 1928, 25 days before "totality" began, and October 25, 1929, three days after "totality" ended, showing photographs taken with the 40-inch refractor and a three-prism spectrograph. Tracings of the line intensities are shown below. The strongest lines seem to show the greatest asymmetry, except for Mg II 4481. Yerkes Observatory photo.

came conspicuous at the beginning of totality. After totality the lines became strikingly unsymmetrical in the opposite sense, with the violet edges steep and the red edges much less so. This phenomenon persisted about two or 2½ years after the end of the photometric eclipse in the middle of 1930.

We refer to these distortions of the spectral lines, which are associated with a stellar eclipse but which begin earlier and last longer, as caused by an "atmospheric eclipse." The phenomenon is known in other stars: A recent paper by D. B. McLaughlin (*Publications,* Astronomical Society of the Pacific, August, 1952) contains a detailed description of four supergiant binary systems with atmospheric eclipses, VV Cephei, Zeta Aurigae, 31 Cygni, and 32 Cygni. Epsilon Aurigae, with its long period, is the fifth in this group.

It must be understood that when we speak of an atmospheric eclipse, we mean that the light of the more distant component, the one that is about to be eclipsed, shines through a thick layer of gas in the atmosphere of the component that is doing the eclipsing.

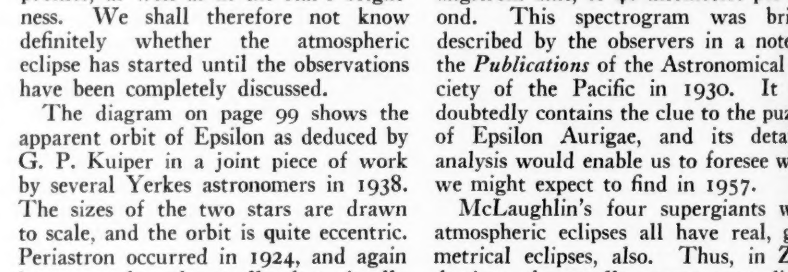
If the observations of 1926 are reliable, we should expect that the atmospheric eclipse would start in the beginning of 1953. Observations of the spectrum with the great coude spectrograph of the Mount Wilson 100-inch telescope show that many spectral lines have been slightly unsymmetrical, in the expected sense, since 1951, and they were rather strikingly so in the latter part of 1952. These same lines were quite symmetrical in 1950. It is therefore possible, and even probable, that the atmospheric eclipse is in progress at the present time. But there are also present irregular variations in the line profiles, as well as in the star's brightness. We shall therefore not know definitely whether the atmospheric eclipse has started until the observations have been completely discussed.

The diagram on page 99 shows the apparent orbit of Epsilon as deduced by G. P. Kuiper in a joint piece of work by several Yerkes astronomers in 1938. The sizes of the two stars are drawn to scale, and the orbit is quite eccentric. Periastron occurred in 1924, and again in 1951, when the smaller but visually brighter component was approximately in the position shown in the drawing. It has receded since then, but it has, of course, not yet reached the point where it begins to disappear behind the limb of the large component.

Since the atmospheric eclipse begins two or 2½ years earlier than the photometric eclipse, it is reasonable to suppose that the large component has no sharply defined limb, or edge, and that its tenuous gaseous "corona" extends at least as far as the location of the smaller star when at periastron. This would mean that the over-all dimensions of the larger component could be twice as large — 6,000 times those of the sun, or as far out as the orbit of Neptune!

Probably the small, bright component, as it passes periastron, has actually dipped into the gaseous corona of the large star. Whether it remains close enough to the large star to stay inside this cloud during the actual eclipse is not known, but since it will recede to ever greater distances from the sun until about 1957, its rays will then shine through the greatest thickness of "atmosphere" of the large component. Similar conditions prevailed in 1930, and it was on February 6th of that year that W. S. Adams and R. F. Sanford obtained what is perhaps the most remarkable spectrogram ever made of any star: a superposition of two sets of absorption lines, displaced with respect to one another by about two thirds of an angstrom unit, or 40 kilometers per second. This spectrogram was briefly described by the observers in a note in the *Publications* of the Astronomical Society of the Pacific in 1930. It undoubtedly contains the clue to the puzzle of Epsilon Aurigae, and its detailed analysis would enable us to foresee what we might expect to find in 1957.

McLaughlin's four supergiants with atmospheric eclipses all have real, geometrical eclipses, also. Thus, in Zeta Aurigae the smaller component disappears completely from our view during the total phase, and the light we ob-



The velocity curve of Epsilon Aurigae, showing the relative motions of approach and recession from 1900 to 1940, as measured in the spectral lines of the visible component. Potsdam observations are open circles; Yerkes, solid dots. The velocity curve of the invisible star is shown dotted, on the assumption of a mass ratio of 1.3 for the bright star to 1 for the invisible star. The two vertical lines indicate approximately the first and last contacts of the most recent eclipse. Note the asymmetrical behavior of the lines during the eclipse, changing rapidly from excess positive (red) shifts to negative (violet) shifts at mid-eclipse, as shown by the faint dotted line. Reproduced from the "Astrophysical Journal."

serve in that phase is the red glow of the large supergiant.

But in Epsilon Aurigae the small star is never completely extinguished. In a sense the entire eclipse is atmospheric. The light we actually record on blue-sensitive plates, even during the flat-bottom part of the light curve, is that of the small star, with all its usual spectral lines. The large star superposes its own set of atmospheric absorption lines, and it reduces the light of the small star by the action of something like an ionospheric outer layer — a region in the atmosphere of the large star that is ionized by the ultraviolet light of the small star and is thereby rendered partially opaque. The theory of this process was developed in 1938 by B. Stroemgren.

The nature of the large star can only be inferred by an indirect method. Kuiper found that the masses of both components could be estimated when he assumed that the small star, a supergiant of class *F*, obeyed the mass-luminosity relation. The two then turn out to be similar in mass, about 40 times that of the sun. The luminosity in all radiations must then also be about the same for both components, about 60,000 times that of the sun, provided again that both obey the mass-luminosity relation.

But the large star, with its 10 times greater radius, has 100 times the surface area of the *F* component. It has therefore a much smaller surface brightness, and a temperature of only 1,000°. Kuiper designated it as an infrared I-star, invisible in ordinary light because of the glare from the *F* star, but presumably quite rich in radiations around 10,000 angstrom units.

Some early observations by J. Hall in 1930 with an infrared-sensitive photoelectric cell seemed to show an excess of infrared light in the combined radiation of the two components, out of eclipse. And Kuiper interpreted Hall's work to mean that the temperature of the I-star is 1,350° C., with a maximum intensity in the continuous spectrum at a wave length of about 20,000 angstroms.

But later observations, by Kuiper himself, and more recently by A. E. Whitford, with special infrared detecting devices, have failed to show any light from the I-star at 2.2 microns. The reddening found by Hall may, according to Whitford, be ordinary interstellar absorption; Epsilon Aurigae is very luminous, and its distance may well be of the order of several thousand light-years.

The absence of infrared radiation may mean only that Kuiper's estimates were not drastic enough and that the dark star is even cooler than he had supposed. In order to test this, observations with lead-sulfide cells will doubtless be made during the coming eclipse when the *F* star is greatly reduced in brightness.

On the other hand, the nature of the infrared star may even now be a secret. The assumption that both components obey the mass-luminosity relation is plausible, but not binding. And there are other unavoidable uncertainties in fixing the masses of the two stars. Even the radius of the dark star is but vaguely defined. Is it the radius of Stroemgren's ionized "ionospheric" layer? Or is it the radius of the "atmosphere" that produces anomalies in the spectral lines?

All we can be reasonably certain of is that the dark component is an enormous, tenuous mass of gas whose ionization springs from the light of the *F* star. This gaseous mass is invisible in all wave lengths accessible to us — for all practical purposes it is dark and cold — except in the ionized layer illuminated by radiation from the *F*-type supergiant.

One question which has caused some uneasiness about the acceptance of the original Kuiper-Struve-Stroemgren interpretation is the fact that the ionized shell of the I-star produces a modified *F*-type spectrum. There are apparently no absorption features from any of the vast thicknesses of gas that lie inside the ionized layer. A gas whose temperature is 1,000° might be expected to absorb strongly in certain molecular bands. None has been found — although the search has not been too exhaustive.

It is uncertain whether the dark star should really fall upon the mass-luminosity curve. If it does not, then its temperature is unknown. In either case, it is a celestial object, perhaps not even to be distinguished by the word *star,* unlike any other that has ever been discovered.

Amateur Astronomers

Astronomical League Takes Part in Section D Meeting

SEVENTY-EIGHT professional and amateur astronomers met in St. Louis on December 29th at the meeting of Section D of the American Association for the Advancement of Science. Dr. Charlotte Moore Sitterly, National Bureau of Standards, presided over the regular session for papers, after which Dr. Harold L. Alden, Leander McCormick Observatory, presided over a session arranged by the undersigned for the Astronomical League.

At the amateur session, three papers were given: "The Amateur in Astronomy," by Rolland R. LaPelle, president of the league; "Activities of the AAVSO," by David W. Rosebrugh; and "Future Plans and Activities of the Astronomical League," by Grace C. Scholz, executive secretary of the league, and the writer.

A feature of this session was the address by Dr. Alden, retiring vice-president of Section D, who described the progress of positional astronomy during the past 100 years.

Russell C. Maag
Chairman, Mid-States Region
Astronomical League

THIS MONTH'S MEETINGS

Buffalo, N. Y.: Buffalo Astronomical Association, 8 p.m., Buffalo Museum of Science. Feb. 4, reviews of current astronomical articles, by club members.

Dallas, Tex.: Texas Astronomical Society, 8 p.m., Dallas Power and Light Co. auditorium. Feb. 23, sound film, "Nautical Astronomy."

Geneva, Ill.: Fox Valley Astronomical Society, 8 p.m., City Hall. Feb. 10, William Siekman, "Refracting and Reflecting Surfaces of Telescopic Mirrors."

Indianapolis, Ind.: Indiana Astronomical Society, 2:15 p.m., Central Library. Feb. 1, Dr. Harry E. Crull, Butler University, "Sky Photography."

Milwaukee, Wis.: Milwaukee Astronomical Society, 7:45 p.m., Milwaukee Public Library. Feb. 9, Robert A. Jaggard, Milwaukee Vocational School, "Physics, Tool of the Astronomer."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. Feb. 4, Dr. Bart J. Bok, Harvard Observatory, "The Southern Milky Way."

Rutherford, N. J.: Astronomical Society of Rutherford, 8 p.m., YMCA. Feb. 5, Willard B. Savary, "Famous Meteor Craters."

Sacramento, Calif.: Sacramento Valley Astronomical Society, public meeting, 8 p.m., Little Theatre, Sacramento Junior College. Feb. 3, Dr. Harold F. Weaver, University of California, "Astronomical Problems of the Earth's Atmosphere."

San Diego, Calif.: Astronomical Society of San Diego, 7:30 p.m., Gas and Electric building. Feb. 4, Frank Bonham, Senior High School, "Volcanoes in Lassen National Park."

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Building auditorium. Feb. 7, Dr. Hari K. Sen, National Bureau of Standards, "The Hydrogen Bomb in the Sun."

Graphic Time Table of the Heavens -- 1953

Discussion by Paul W. Stevens

PART II

We here continue from last month the discussion of various special features of the Graphic Time Table of the Heavens, and of information that can be deduced from it. We were discussing the harvest moon, and had pointed out that a line drawn parallel to the VERNAL EQUINOX line on the Time Table, and through the position of 18 hours sidereal time on the midnight line, indicates times from March to September when the moon at other phases than full shows small changes in rising time.

A similar situation occurs at moonset when the moon is near the autumnal equinox, and the same line indicates these times on the chart. The small daily retardation of moonset is familiar to those who schedule observing parties on summer evenings under a golden crescent.

Perigee and Apogee: Compare the intervals between the black dots to those between the open circles that bridge the 18-hour line we have drawn. The former are a little closer together than the latter. This indicates that the moon is moving more slowly among the stars and hence is farther from the earth at the times of the black dots than at the times of the open circles. Moreover, the minimum retardations of rising and setting are both slightly to the left of the 18-hour line. These observations combine to tell us that in the middle of 1953, the moon's perigee is a little west of the vernal equinox while apogee is a corresponding distance west of the autumnal equinox.

Sidereal Time. The slanted line labeled VERNAL EQUINOX (hereinafter called the VE line) indicates the local civil time of transit of that celestial point. It is then 0 or 24 hours by the sidereal clock so that the line crosses the midnight line where the sidereal scale so reads. Similarly, any other line drawn parallel to the VE line will be the locus for some other time by the sidereal clock. All the transit curves for stellar objects are such parallel lines and indicate when the sidereal time equals the right ascension of the body in question.

Furthermore, such a line may be drawn to determine the sidereal time at any hour of any night throughout the year. For evening hours in winter or morning hours in autumn, it may be necessary to extend the sidereal scale on the midnight line above or below the chart. However, to the degree of accuracy to which the Time Table can be read, it will suffice to apply the local civil time difference to the sidereal hour at midnight. For instance, at 9 o'clock on any evening, the sidereal time is essentially three hours earlier than the scale reads for the middle of the same night.

It will be noticed that the slant of the VE line is nearly that of the diagonals of the elementary rectangles into which the time table is divided. Since the horizontal sides of these figures represent intervals of one half hour of mean time, while the vertical sides represent a week, the slope of the VE line would equal that of the diagonals if the sidereal clock gained on the mean solar clock exactly 30 minutes per week. This would require a year of 48 weeks. The actual gain in one week is about 27 minutes, 36 seconds.

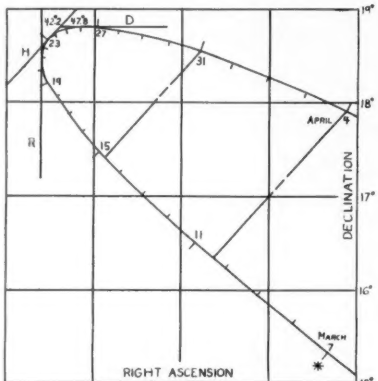


Fig. 1. The path of Venus in the sky, and the relation of the planet's position to its times of setting.

Equation of Time. As it stands on the chart, this may be considered to be the local civil time of lower culmination of the apparent sun. The curve for the equation of time is precisely midway between those for sunset and sunrise. Except for the four times during the year when this equation is zero, a line parallel to the VE line will intersect the curve and the midnight line on two different dates and give the right ascension of the sun plus or minus 12 hours.

As an example, consider the line of transit of the Pleiades, M45. This gives the right ascension of the cluster as $3^h\ 45^m$ and shows that it transits at midnight, local civil time, on the night of November 17-18. But the intersection with the equation of time comes on November 21 and tells us that on this date the right ascension of the sun is $15^h\ 45^m$.

Where the VE line intersects the midnight line, sidereal time agrees with the mean solar clock. This occurs in September about two days before the apparent sun reaches the autumnal equinox, the latter being indicated by the intersection of the VE line with that for the equation of time.

On the average, opposition of a planet to the sun occurs on the date that its transit curve intersects the equation of time. This is strictly the moment when the right ascensions of sun and planet differ by 180 degrees, whereas at true opposition their celestial longitudes differ by this amount. The two occur at the same time if the planet is on the ecliptic. However, if it is far from the ecliptic, as in the case of Mars at its most favorable oppositions, there is an appreciable interval between the two times.

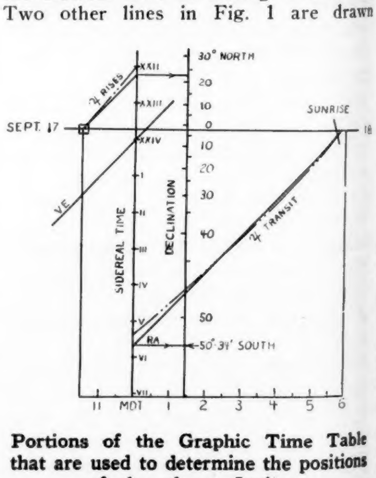
Retrograde Motions of Planets. The transit lines of the superior planets are slightly curved because of planetary motion, including that of the earth. Each is parallel to the VE line on those dates when the planet charted is stationary in right ascension. The retrograde motion of Saturn can be verified by comparing its curve to that of the lower culmination of Polaris. It is stationary on February 5 and June 24.

This method cannot be applied to the inferior planets because they always culminate in the daytime and their transit curves are not shown on the chart. An approximation can be made by noting the dates when the curves for rising or setting are parallel to the VE line. These are actually the dates when the apparent path of the planet among the stars is parallel to the horizon at the time of rising or setting.

Fig. 1 shows the analysis for Venus in the evening skies of 1953. The celestial co-ordinates are plotted from March 7, the date of its greatest brilliancy, through April 4. They are for 0^h UT on the following day, which is 6 o'clock in the evening of the date listed at the standard station at 90° west longitude.

Three straight lines are drawn tangent to the curve. The vertical one, **R**, indicates that Venus is stationary in right ascension on March 21. The horizontal one, **D**, shows that maximum declination is not reached until March 26. The inclined one, **H**, is parallel to the horizon at the time that Venus is setting. Its angle with **R** would be exactly 40 degrees, the latitude of the station, if the planet were on the equator. (The northerly declination increases it to 42.2 degrees.) This is because **R** is an hour circle passing through the celestial pole, and the elevation of the pole above the horizon equals the observer's latitude.

The line **H** is tangent to the curve on March 23. On the Graphic Time Table, the VENUS SETS curve is parallel to the VE line on this date. This means that the sidereal time of setting is constant. Two other lines in Fig. 1 are drawn



Portions of the Graphic Time Table that are used to determine the positions of the planet Jupiter.

parallel to **H**. One signifies that the sidereal time of setting is about the same on March 31 as on March 15, while the other makes a similar comparison for April 4 and March 10. Lines connecting the corresponding points on the setting curve on the Time Table would be parallel to the VE line.

Rising and Setting Scale. As this scale is constructed, it takes into account refraction of the atmosphere as it affects the times of rising and setting of celestial objects. The accepted value of the vertical displacement of the apparent horizon due to refraction is 34 minutes of arc. Since the chart is drawn for a standard latitude of 40°, the declinations of the meridian at the northern and southern horizons would be plus and minus 50 degrees, respectively, if there were no atmosphere. However, refraction elevates to the horizon points that actually are 34 minutes of arc below it. Accordingly, the observed declinations at the horizon become +49° 26′ and −50° 34′. As a result, objects which would just graze the southern horizon at latitude 40° north, if there were no atmosphere, are visible for about 45 minutes before and after they cross the meridian.

Right Ascension and Declination of the Sun and Planets. These can both be measured from the chart and the scale if the times of transit and rising (or setting) of the body are known. (The times of rising and setting would do just as well because culmination occurs midway between and is thereby easily determined.)

Consider the planet Jupiter on the date of western quadrature, September 17. The graphical determination of co-ordinates is shown in Fig. 2. This is a proportional representation of the essential features on the chart, together with auxiliary lines used in the solution.

From the point where the JUPITER TRANSIT curve intersects the date line for September 17-18, a line drawn parallel to the VE line meets the sidereal time scale at $5^h\ 40^m$, the right ascension of the planet. A similar line is drawn with respect to the JUPITER RISES curve. The intercept of these two on the sidereal time scale is then carried over to the declination scale reproduced just to the side (note the arrows). This is just the reverse of the procedure in the instructions for finding the time of rising when the co-ordinates are given. In this case, the declination of Jupiter is +22° 47′.

Mutual Conjunctions of Two Planets. The relative declination of two planets, at the time of conjunction in right ascension, is easily estimated by inspection. Thus on March 17, Venus sets about 25 minutes after Mars, and therefore is considerably to the north of it (7°.0). On the other hand, Mars is much closer to Jupiter (1°.1 N.) on April 27, when it sets about four minutes later than the giant planet. A number of easily observed planetary conjunctions take place in 1953.

Celestial Latitudes of Planets at Conjunction with the Sun. If a planet sets with the sun on a given evening and then rises ahead of it the following morning, it is generally north of the ecliptic. If it rises later than the sun, it is south. Thus in April, 1953, Venus passes well to the north of the sun at inferior conjunction and should be easily observed during both morning and evening of the same date.

This year brings the rather rare circumstance of a transit of Mercury upon the solar disk. During the transit seasons in May and November, the earth crosses the line of nodes of the planet. If inferior conjunction takes place at this time, a transit occurs and is predicted, but if superior conjunction takes place, it is an unheralded occultation of Mercury by the sun that occurs. After the season in May and before that in November, superior conjunction is always north of the sun and inferior is south. During the rest of the year, the reverse is the case. This can be verified from the Time Table. The situation is the same with Venus except that the transit seasons come early in June and December.

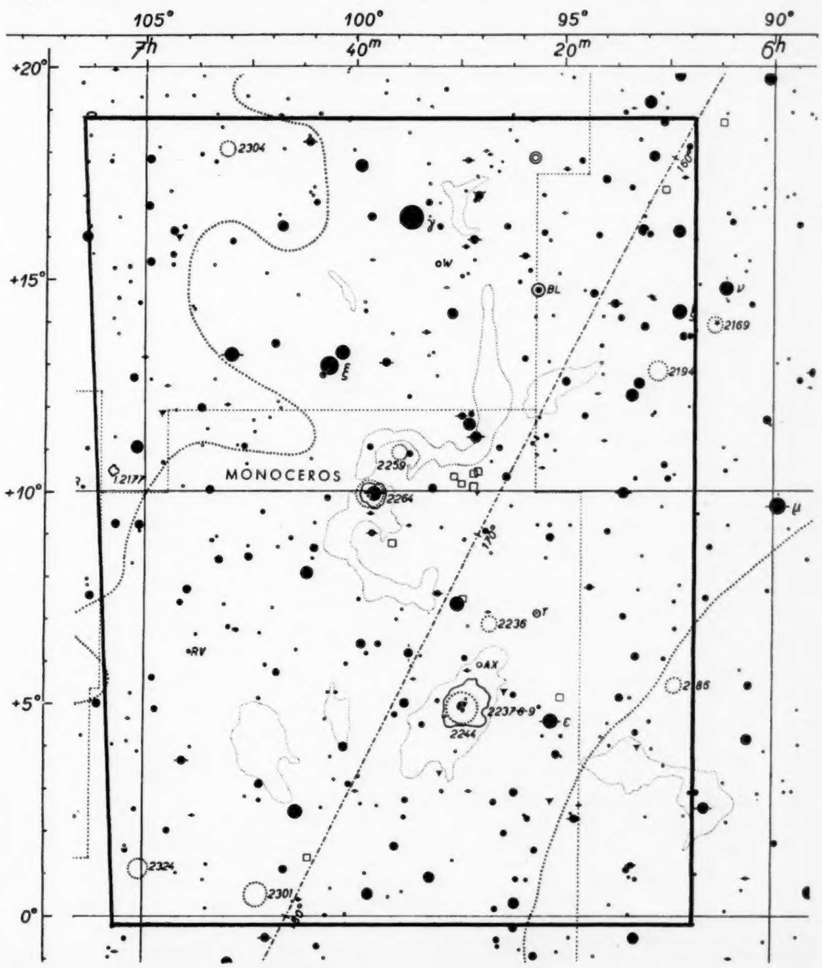
The conditions that exist in the case of opposition of a superior planet merit special attention. If it rises after sunset and sets before sunrise, it must be south of the ecliptic. However, if opposition occurs at a node, the planet will rise before sunset and set after sunrise. This discrepancy is in part due to the solar diameter, an effect that also influences the situation at conjunction. The more important factor is atmospheric refraction, which serves both to shorten the night and to lengthen the period that the planet is above the horizon. (At the time of conjunction, the effects of refraction cancel out.) Thus at opposition in 1953, both Saturn and Jupiter set after sunrise following the evening when they rise at sunset. Saturn is north of the ecliptic, but Jupiter is south of it.

All of such considerations are modified by the apparent motions of the sun and planets against the stellar background, as well as the solar diameter and atmospheric refraction. The analysis is therefore approximate, but serves readily to identify any appreciable latitude north or south of the ecliptic.

In Focus

THIS MONTH'S back cover is reproduced from Plate 35 of the Ross-Calvert **Atlas of the Northern Milky Way.** It shows a region along the galactic equator that is populated with a variety of objects, including the Rosette nebula, NGC 2244, which was pictured on the back cover of **Sky and Telescope** in October, 1949.

The part of the sky that is included in the back cover is here marked by the ruled area on a part of Chart VII of the Skalnate Pleso **Atlas of the Heavens.** The galactic equator is shown by the dashed line. The region along the right side is in Orion; along the top is Gemini, with the star Gamma Geminorum centered near the top. The chart shows stars to a limiting magnitude of 7.75 visual.



BOOKS AND THE SKY

INSIGHT INTO ASTRONOMY

Leo Mattersdorf. Lantern Press, Inc., New York, and Sky Publishing Corporation, Cambridge, 1952. 223 pages. $3.50.

IN **Insight into Astronomy,** the author, who is president of the Amateur Astronomers Association of New York City, has attempted the difficult job of explaining astronomical facts in language simple enough to be understood by those having no previous acquaintance with the subject. In thus aiming his book at the totally uninitiated, the author has cut himself off from mathematical explanations, and is forced to rely on descriptive word pictures to convey even such simple mathematical concepts as the planets' period-distance relationship, and the relation between visual and absolute magnitude.

In spite of this handicap, the present reviewer feels that the author has succeeded very well in producing clear, readable explanations, easily understood by the general reader. Those having some previous knowledge of astronomical literature will perhaps find the book a trifle oversimplified, and given to too definite statements of some still controversial conclusions. However, there is a vast general public that can be reached by such a book as this, and whose interests may be excited by the material it contains. For those wishing additional light, there is an excellent bibliography which recommends further reading material.

The book begins by presenting in brief, easily read chapters the basic facts about the moon, the sun, the terrestrial planets, the giant planets, the "discovered" planets (Uranus, Neptune, Pluto), the asteroids, and comets and meteors. An all-too-brief chapter treats of the stars, touching upon the astronomical spectroscope, stellar distances, apparent and absolute magnitudes, and variable stars. The constellations are briefly explained, and four, Ursa Major, Scorpius, Pegasus, and Orion, are described in some detail. The idea of proper motion is introduced through the description of the stars of the Big Dipper, and a list of the 20 brightest stars is given, together with the pronunciation of their names, and those of their constellations, as well as their apparent and absolute magnitudes, and their distances.

The remainder of the book, with the exception of a short chapter on the Milky Way and galaxies, is devoted to terrestrial astronomy, including navigation, precession of the equinoxes, eclipses, including the saros cycle, the tides, various kinds of time, and the calendar. These are all covered briefly and quite well, though this reviewer felt that the considerable amount of space devoted to the saros might better for the newcomer to astronomy have been used for such untouched matters as the globular and galactic clusters, and gaseous nebulae.

The author is to be particularly commended for the pronunciations that are given for all the star and constellation names. This matter of pronunciation is one which often causes much difficulty — not to mention embarrassment — to the amateur, and to the professional as well. As a matter of fact, judging from lectures the writer has heard, it would appear that many professional astronomers have their own private pronunciations for some of the names, leading to much confusion among their hearers, especially since many of the pronunciations do not seem to follow standard rules of their basic languages. This reviewer could wish that Mr. Mattersdorf would publish a really comprehensive pronouncing dictionary of astronomical terms — although he supposes that even then it would take legislation by the International Astronomical Union to persuade all the professionals to adopt it!

In his conclusion, the author cites the various amateur astronomical organizations to which those interested may turn for help in astronomy, in telescope making, or merely for fellowship with others interested in the sky. The Astronomical League and its numerous member organi-

zations throughout the country are recommended by the author to those whose interest has been excited by the book. We echo his recommendation, and feel that through this new volume an increasing number of persons will learn the beauty and fascination of the heavens, and desire to learn still more about them. Thus the purpose of the book will have been well served.

ROLLAND R. LaPELLE
President, Astronomical League

COMETS AND METEOR STREAMS

J. G. Porter. Chapman and Hall, Ltd., London, and John Wiley and Sons, Inc., New York, 1952. 123 pages. 28s., $5.25.

DR. J. G. PORTER, principal scientific officer of H. M. Nautical Almanac Office, has provided an interesting and useful book. This is the second in the International Astrophysics Series.

The volume consists of seven chapters: Comets (General), The Orbit of a Comet, Cometary Statistics, Perturbations, Meteor Streams, Meteor Orbits, and Meteor Velocities. Three appendices follow: Calculation of an Ephemeris, Conversion of R. A. and Dec., and Calculation of Meteor Orbits.

The first chapter presents general nomenclature, physical and then photometric aspects of comets. Chapter Two is a straightforward statement of the orbital parameters, the equations of motion, motion and position in the orbit, and a brief introduction to the computation of an orbit and an ephemeris. Some interesting aspects of motion about the "empty focus" for eccentricities near 0.7 are included.

Important statistics of cometary orbits are presented, and discussed in a cautious manner in view of the severe selection effects influencing discovery. Short-period comets are defined as "all those comets which have made more than one return to the Sun during the time in which accurate records have been kept." This extends the usual definition of this class to include comets with periods up to 200 years. Here the author shows his considerable experience by noting the high sensitivity of orbital parameters, especially of the period, to slight variations in the observed positions. His tabulations show clearly that short-period comets usually have orbits of low inclination with their line of apsides close to their line of nodes (ω near 0° or 180°), which keeps their long axes close to the planetary plane.

The possibilities of comet groups is discussed at some length. Porter does us a kindness by reminding us that the gravitational force on a comet, or a fragment of a larger comet, is proportional to the mass of the sun plus that of the smaller body. If two cometary fragments have differing masses, they will move under slightly different solar attractions and drift apart, especially in date of perihelion. Regarding the number and origin of comets, he reports in particular the conclusions of van Woerkom and of Oort.

The chapter on perturbations is a short but clear introduction, with illustrations, to how computations proceed. It states clearly what operations are being done and why. The appendices give fuller details of procedure.

Various meteor streams are described briefly and their variation, especially in date of appearance, due to perturbations is discussed. On the interrelation between comets and meteor streams, Porter concludes that "the idea of a common origin for a comet and its associated meteor stream is preferable to the assumption of a direct connection." The reviewer agrees that this statement seems the wisest and most definitely supported by the available data. The various corrections to an observed meteor radiant and velocity are clearly presented, followed by a terse description of how a meteor orbit may be determined. Similarly, the prediction of a radiant point from a comet orbit is clearly presented.

After brief discussion of the velocity results obtained visually by von Niessl, Hoffmeister, Opik, photographically by Whipple, and with radar by a number of observers, Porter states: "The conclusion is inevitable that all meteors, like comets, are members of the solar system." This closes for the present, at least, a subject of much controversy.

The three appendices are terse and clear. The computation of cometary orbits is illustrated in detail, both with logarithms and with machine calculation.

This book will be a boon to those seeking a brief yet authoritative source dealing with these studies.

FLETCHER G. WATSON
Harvard University

GLEANINGS FOR ATM's

EDITED BY EARLE B. BROWN

An Improved Herschelian Telescope

Many large telescopes, both of the reflecting and refracting types, have been in use for the past 50 years or so, and it has now become apparent that the large apertures of most recently constructed instruments, while they reveal hitherto unseen stars and nebulae, show little more detail on the moon or planets than the moderate apertures of half a century ago.

In the case of a reflector, the diffraction effects caused by the secondary mirror and its supports result in a scattering of light from the image of a point. This effect was investigated by Pickering, and his conclusions were that it was so detrimental in Newtonians as to be responsible for enlarging a point image as much as two to five times the proper theoretical size. More recent investigations confirm Pickering's findings, and, as experiments with different apertures have shown, the effect is much more pronounced in large apertures. It is difficult to imagine a reflector of 200-inch aperture, equipped with a secondary one third of this size, proving to be of much special use for planetary studies.

It is generally conceded that refractors are more suitable for planetary detail. However, the secondary spectrum caused by the combination of even the best of modern glasses, together with the inevitable flexure of large lenses, places a limit on the amount of detail that can be seen with refractors.

As for electronic and radar telescopes, admirable though they may be for certain kinds of observations, they are unlikely to be suitable for the delineation of fine planetary detail, and we are left with the reflecting telescope as the best solution to the problem of discovering more about our nearest neighbors in space.

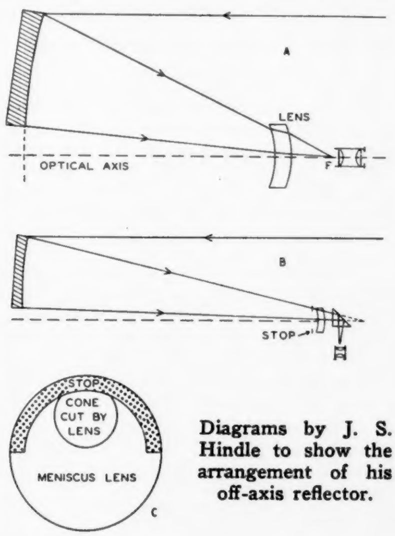
The Herschelian type of off-axis reflector, if used in conjunction with a slightly positive meniscus lens of about one fifth the diameter of the mirror, will result in greatly improved detail—so much so that detail on the lunar Straight Wall, claimed to be only just visible in the 24-inch refractor of the Lowell Observatory, is easily visible with a 10-inch Herschelian used in the poor viewing conditions of industrial Lancashire.

The optical arrangement of the new system,* in its simplest form, is depicted in A of the diagram, but to avoid the observer's head being placed close to the open end of the tube, it is better to use a prism or flat, as shown in B. It is necessary to give a fairly long focal length to the telescope, ratios between f/9 and f/13 being suitable, the longer preferred. The reason for this comparatively long focus is that the lens corrects for spherical aberration but not for curvature of field or coma. Considering, however, that a good Herschelian telescope will show planetary detail invisible to the Newtonian or Cassegrainian types, this inconvenience is worth tolerating. The writer's 12-inch is regularly used with a power of 600 diameters, sharpness of definition being practically as good as when using only 60 power. What Newtonian could pass this test?

The following specifications apply to a 12-inch aperture; other sizes may be used by substituting suitable figures in the same proportions:

Aperture of mirror, 12"; focus of mirror, not less than 9'; diameter of correction lens, about 2½"; thickness of lens, about 3/8" to 7/16"; radius of curvature for concave side, 30"; radius of curvature for convex side, 29-13/16"; glass for lens, borosilicate crown of low dispersion and index about 1.5. The curve of the mirror and both curves of the lens are spherical, a help to easy construction.

It should be noted that the only measurement demanding precision is the slight difference in the curves of the lens, which is very slightly positive. This small difference is necessary to ensure that the rays emerging from the convex side of the lens will do so at the same angle as they impinge on the concave side—an essential condition of perfect achromatism in the image. The actual difference in radius required with glass of about 1.5 index is about half the thickness of the lens, and not more than 1/16" error plus or minus may be tolerated.



Diagrams by J. S. Hindle to show the arrangement of his off-axis reflector.

The best method of making the lens is to polish the concave side first. The convex side can then be tested from the concave side. As the two curves are so nearly alike, it will be found that the image of the pinhole cast by the convex side is displaced about an inch or so from the image formed by the concave side. Thus, the two surfaces may be judged easily by the ordinary Foucault shadow test, making sure, of course, to move the lamp a suitable distance so as to get pin-

* Mr. Hindle has constructed a catadioptric Herschelian of the sort for which specifications are given by Maksutov (**Journal**, Optical Society of America, 34, 270, 1944). From the performance reported here, it is evident that the theoretical predictions for the quality of such a system are well borne out in practice.—ED.

hole and image the same distance from each surface.

When the lens is mounted in the telescope, it should be provided with means for adjustment to or from the mirror, independent of the rack and pinion on the eyepiece. For the size given here, the distance between lens and eyepiece will be about 8", but this will vary with the types of optical glass and focal lengths used.

The lens must also be provided with a stop for cutting out unwanted light from the outer edge of the field. In the case of short focal lengths it will be better to cut down the actual cone of light just where it meets the lens to the shape shown in C. This shape has been found to give images as good as those from a circular aperture. The size of the stop is best found by experiment with bits of cardboard.

Note that the mirror must have no trace of turned edge. If any is present, the mirror should be stopped down, as a turned edge has a worse effect on the Herschelian than on a Newtonian. The best eyepieces are monocentrics or Ramsdens, preferably of the achromatic type. Huygens eyepieces are not recommended, as they tend to annul the correction for spherical aberration.

J. S. HINDLE
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Bolton, Lancashire, England

STILL LUNAR PHOTOGRAPHY

ROBERT G. KNITTEL, director of the New York Amateur Astronomers Association camera station, comments in the following letter on the problem of photographing the moon through a telescope, which was partly the subject of an article in this department by Allyn J. Thompson in February, 1952.

I will discuss in this letter the snapshot method of photographing the moon, with the telescope stationary and motionless. The moon's image will move across the film at an angular speed equal to that of the earth's rotation diminished by the moon's proper motion around the earth. The latter, amounting to roughly ½ second of arc per second of time, may be regarded as of negligible amount, and the image motion across the film may be taken as due solely to the earth's rotation. This, in a time interval of ½ second, would be an angular shift of 7½ seconds of arc.

This exceeds by many times the angular resolving power (about ¾ second of arc) of a 6-inch telescope. But in taking pictures of the moon, it is not so much the resolving power of the telescope objective that is involved, but the resolving power of the film itself. Most popular films have a resolving power of 2,500 lines per inch, so that if any point in our image moves more than 1/2,500 of an inch, the motion will be detected as a blur on the negative. If our image is half an inch in diameter, which may be considered average for the 6-inch telescope, then the maximum allowable motion will be 1.4 seconds of arc. For a larger image, this maximum allowable motion would be less than 1.4 seconds of arc, that is, for a one-inch

image, 0.7 second of arc; for a two-inch image, 0.35 second of arc.

If, however, we shorten the exposure to 1/10 second, we can divide the motion by five and arrive about at our maximum allowable motion figure for a half-inch image. This means that 1/10 of a second is the longest exposure permissible in picture taking of this type.

For a one-inch image, the maximum allowable motion for the resolving power of the film becomes 0.7 second of arc, lower than the resolving power of the 6-inch telescope. We must shorten the exposure to about 1/20 second, but any image larger than one inch can be given this same exposure and still be within the resolving power of the 6-inch instrument.

This discussion may seem to be splitting hairs, but if we are to obtain the best possible photographs, we want at least to "stop the motion" of our object, and these exposures are necessary to do that. This obviously rules out an exposure of ½ second for any size of image when photographing the moon.

ROBERT G. KNITTEL

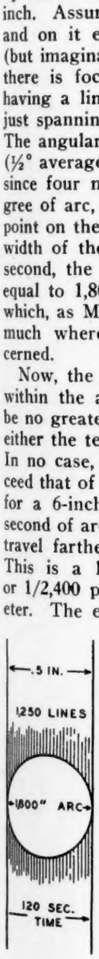
Mr. Thompson has furnished the following comment:

My comments on Mr. Knittel's letter require the aid of the accompanying diagram, in which **a** and **b** represent strips of film having a resolving power stated by the manufacturer to be 2,500 lines per inch. Assume strip **a** to be ½ inch wide, and on it envision 1,250 just discernible (but imaginary) parallel lines. On it also there is focused an image of the moon having a linear diameter of half an inch, just spanning the width of the film strip. The angular diameter of the lunar image (½° average) is 1,800 seconds of arc. And since four minutes of time equal one degree of arc, the time required for a given point on the moon's image to traverse the width of the strip is 120 seconds. In ½ second, the point would move a distance equal to 1,800/240, or 7.5 seconds of arc, which, as Mr. Knittel says, is entirely too much where a 6-inch telescope is concerned.

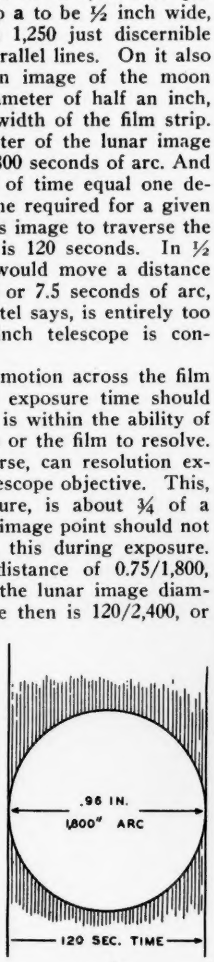
Now, the image motion across the film within the allotted exposure time should be no greater than is within the ability of either the telescope or the film to resolve. In no case, of course, can resolution exceed that of the telescope objective. This, for a 6-inch aperture, is about ¾ of a second of arc. An image point should not travel farther than this during exposure. This is a linear distance of 0.75/1,800, or 1/2,400 part of the lunar image diameter. The exposure then is 120/2,400, or 1/20 of a second. But in the case of **a**, the film would be insensible to a motion, and would not resolve detail, less than 1/1,250 part of the lunar image diameter. And since in this case the film structure is the factor limiting resolution, exposure may be as long as 120/1,250, or 0.096 (call it 1/10) of a second.

Obviously then, in order to utilize the superior resolving power of the telescope objective, a larger image is needed. This can be had with either a Barlow lens or an eyepiece. But how large an image, or to put it another way, what size image, just brings film resolution up to that of the telescope? The formula, 1,800/2,500**D** (where **D** is the telescope's resolving power in seconds of arc), gives us the answer. For a 6-inch telescope, it is a diameter of 0.96 inch. This is the case at **b**, where the image spans 2,400 mythical lines on the film. The limit of exposure here is 120/1,800 × 0.75, or 1/20 second. This 1/20 of a second is, with a 6-inch telescope, the limiting exposure time regardless of image size, **as far as telescope resolution is concerned.**

But nothing has been said about film sensitivity or image intensity. The intensity at **b**, where the image has been practically doubled, is only about one fourth that at **a**, so that whatever exposure was proper at **a** in order to get a good picture should be quadrupled at **b**. If, as is quite likely, a half-inch image from a 6-inch objective requires an exposure of about 1/25 second on Super-XX film, it is apparent that, depending on focal ratio, image size, film sensitivity, moon phase, and atmospheric transparency, exposures must



a



b

vary over a rather extensive range. Consequently, the longer exposures needed to secure good pictures of large images may entail sacrificing some of the telescope resolution. Hence, an overly large image is to be avoided. The optimum size image is one equal to 1,800/2,500**D**. If you are using a 35-mm. camera and a 6-inch telescope, an eyepiece giving a magnification of 56 times will give you about that size of image.

ALLYN J. THOMPSON

AN OPEN-TUBE REFLECTOR

ENCLOSED is a picture of an 8-inch reflector which I built entirely by myself and completed a few months ago. As I am more interested in observing planetary detail and double stars than in photography, I paid particular attention to design factors favoring definition and resolving power. The focal ratio is exactly 1/10, the focal length being 80". The 1" prism was chosen to reduce diffraction to a minimum, although with it small magnifications cannot be employed. The open tube renders steadier images than are obtained with my 6-inch tube reflector, which is subject to air currents.

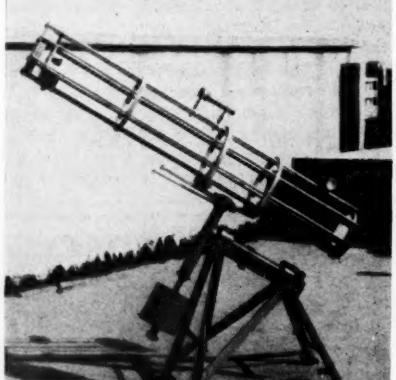


Plate glass of only 7/8" thickness—no thicker glass is available here—served for the mirror, which rests on a nine-point flotation system. The polar axis is a 2-3/8" steel tube, and it runs in ball bearings, which are an absolute necessity in view of the small driving power of a spring-driven gramophone motor; this keeps the telescope moving with perfectly fixed speed for 20 minutes.

Two setting circles and slow motion in declination are provided. Favorable eyepiece positions can be obtained by loosening the two clamping steel bands and rotating the whole telescope tube; this procedure may necessitate some shifting of the main counterbalance.

All six eyepieces I made myself; five of the Ramsden type, giving powers of 60, 120, 180, 300, and 500 times; the other is "solid" and gives 240 power, and it is especially useful for the faint satellites of Saturn. More than 15 craterlets were seen in Plato; one or two spots on Ganymede's disk and the companion of Delta Cygni were seen by a visitor and me.

F. SALOMON
3 Hechalutz St.
Haifa, Israel

OBSERVER'S PAGE

Universal time is used unless otherwise noted.

DEEP-SKY WONDERS

THE INTRICATE SYSTEM of Zeta Cancri, of which we can see three stars, and mathematically deduce a fourth (with Makemson suspecting a fifth), has been a furious center of attention ever since Tobias Mayer discovered it in 1756. With his small, crude instrument, Mayer saw only A and C; in 1781 Herschel caught up B. By 1830 Dawes was proving that AB were in retrograde motion —that is, the value of the position angle was decreasing with time; and the approximate period of 60 years for AB was generally agreed upon.

W. Struve then noticed that C was not following a smooth curve around the center of the AB system (see the diagram), and Seeliger predicted a fourth star, D, revolving in close orbit with C. By 1933 the work of Mrs. Makemson left no doubt about the reality of D. Certain residuals in her orbit of AB led her to suspect even a fifth star as she suggested that A or B might again be double. Van de Kamp by 1947 was writing that D was either double or, more likely, one of the rare white dwarf stars. The orbit of CD is so large that any normal star capable of causing the observed deflections should be easily visible in modern telescopes. The only star with the required mass and the faint luminosity would seem to be a white dwarf. No telescope has ever seen D, and much ink will flow before the secrets of the century-old mystery are revealed.

As it is, we have the three visible stars, all about the size and luminosity of our sun, swinging in great orbits that exceed as a whole the far-flung orbits of the solar system. A and B are as far apart as the sun and Uranus; C and D are almost as distant as the sun and Jupiter; while the two systems AB and CD react on each other over a space that varies from 2½ to five times the radius of the orbit of Pluto. Mrs. Makemson suggests, "One might infer from a study of the Zeta Cancri system that we have by no means reached the outer limits of our own solar system."

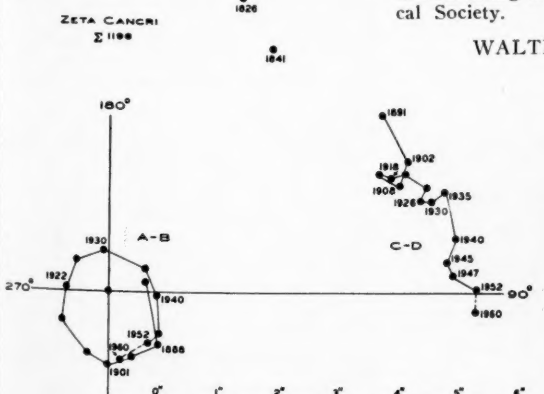
The system is made to order for the amateur astronomer. Both as an object of profound contemplation and as an instrument test it is unsurpassed. The well-separated companion, C, can be detected with as little as one inch of aperture. The AB pair is now a fine test for a 4-inch telescope, and should be easy in larger reflectors, especially those equipped with Barlow lenses. B is now swinging through the widest portion of its orbit and moving most slowly in position angle. Yet, any amateur with even a home-made micrometer should be able to notice the change in position angle in five, certainly 10, years. By 1990, the distance will be a little over half a second; then the star will make a pretty test for the amateur 10-inch and the change in position angle will be detectable in only a year.

This is one of the very few binaries that are rapid enough for an amateur to follow with some success through a couple of decades, and yet widely enough separated to be within the range of small instruments. As such, it should be familiar to every serious watcher of the skies.

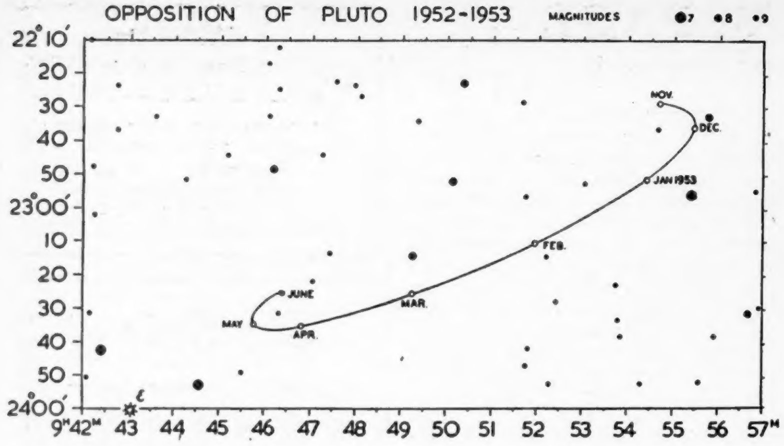
Dr. G. Van Biesbroeck, of Yerkes Observatory, gives the observed positions (1952.27) as 30°.7, distance 1″.07 for star B with reference to A; 90°.4, 6″.14 for star C with reference to A. On the accompanying chart, A is located at the center of co-ordinates. The 1960 positions are obtained by extrapolation, to give an idea of the expected motions in the next few years.

According to Charles Gasteyer, of Yale University Observatory, the period of the AB pair is 59.7 years, in an orbit of eccentricity 0.32; its semimajor axis of 0″.88 corresponds to a linear distance of 19 astronomical units. In 1,150 years the CD pair revolves around the AB pair, in an orbit of eccentricity of 0.26, semimajor axis 7″.5 or 160 astronomical units. The invisible companion of C requires 17.8 years for one revolution, eccentricity 0.11 in an orbit of four astronomical units semimajor axis. Mr. Gasteyer, who studied this system at the Dearborn Observatory during 1951 and 1952, gives the photovisual magnitude of star A as 5.6, star B as 5.9, star C as 6.1; the distance of the system is 70 light-years. Full details of his work have been reported to the Amherst meeting of the American Astronomical Society.

WALTER SCOTT HOUSTON



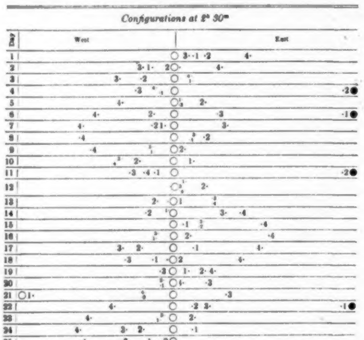
The orbit of Zeta Cancri. This star may be easily found by naked eye by drawing a line from Castor to Pollux and extending it nearly three times its own length. In the diagram, which is by Mr. Houston, note the erratic motion of star C, caused by the attraction of the invisible companion, D.



The path of Pluto, on a chart of stars to the 9th magnitude. South is at the top. The motion during February is retrograde (westward), almost directly toward Epsilon Leonis, shown in the lower left. From the 1953 "Handbook" of the British Astronomical Association.

JUPITER'S SATELLITES

Jupiter's four bright moons have the positions shown below for the Universal time given. The motion of each satellite is from the dot to the number designating it. Transits of satellites over Jupiter's disk are shown by open circles at the left, eclipses and occultations by black disks at the right. The chart is from the **American Ephemeris and Nautical Almanac.**



PREDICTIONS OF BRIGHT MINOR PLANET POSITIONS

Flora, 8, 9.3. Feb. 2, 10:54.4 +13-33; 12, 10:46.1 +14-59; 22, 10:36.1 +16-24. Mar. 4, 10:25.9 +17-39; 14, 10:16.7 +18-36; 24, 10:09.7 +19-10.

Eunomia, 15, 9.5. Mar. 4, 12:30.9 −20-23; 14, 12:23.1 −20-13; 24, 12:14.3 −19-44. Apr. 3, 12:05.3 −18-56; 13, 11:57.2 −17-58; 23, 11:50.5 −16-55.

After the asteroid's name are its number and the magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1953.0) for 0^h Universal time. In each case the motion of the asteroid is retrograde. Data supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, and the result is your standard time on the day preceding the Greenwich date shown.

SUNSPOT NUMBERS

November 1, 19, 14; **2,** 10, 12; **3,** 0, 7; **4,** 0, 0; **5,** 11, 9; **6,** 16, 13; **7,** 34, 32; **8,** [illegible], 30; **9,** 33, 30; **10,** 26, 26; **11,** 26, 23; **12,** [illegible], 16; **13,** 24, 18; **14,** 26, 22; **15,** 20, 23; **16,** [illegible], 15; **17,** 25, 28; **18,** 33, 35; **19,** 38, 43; **20,** 44, 47; **21,** 35, 42; **22,** 33, 39; **23,** 28, 35; **24,** 35, 30; **25,** 24, 28; **26,** 20, 17; **27,** 15, 14; **28,** 4, 8; **29,** 5, 0; **30,** 12, 7. Means for November: 22.5 American; 22.1 Zurich.

Daily values of the observed mean relative sunspot numbers are given above. The first are the American numbers computed by Neal J. Heines from Solar Division observations; the second are the Zurich Observatory numbers.

VARIABLE STAR MAXIMA

Feb. 3, R Caeli, 0437**38,** 8.0; 5, U Herculis, 162119, 7.6; 6, T Herculis, 180531, 8.0; 6, R Indi, 2228**67,** 8.0; 7, RV Sagittarii, 1821**33,** 7.8; 11, RS Herculis, 171723, 8.0; 11, RR Sagittarii, 1949**29,** 6.6; 21, V Cassiopeiae, 230759, 7.9; 25, Z Puppis, 0728**20**b, 7.9. Mar. 1, RT Sagittarii, 201139, 7.9; 3, R Centauri, 1409**59,** 5.9; 3, RU Cygni, 213753, 8.0; 4, X Centauri, 114441, 7.8; 5, T Normae, 1536**54,** 7.4; 6, RU Sagittarii, 1951**42,** 7.2.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

OCCULTATION PREDICTIONS

February 15-16 **Lambda Piscium** 4.6, 23:39.6 +1-31.3, 2, Im: **H** 3:07.2 −0.3 −0.7 77; **I** 3:04.9 −0.2 +0.6 26.

February 25-26 **Delta Cancri** 4.2, 8:42.0 +18-19.7, 12, Im: **A** 0:59.3 −1.6 −0.6 125; **B** 0:56.6 −1.5 0.0 115; **C** 0:55.2 −1.6 −1.3 141; **D** 0:48.2 −1.4 −0.2 123; **E** 0:34.8 −1.2 −0.7 137.

For standard stations in the United States and Canada, for stars of magnitude 5.0 or brighter, data from the **American Ephemeris** and the **British Nautical Almanac** are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard station designation, UT, **a** and **b** quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computation of fairly accurate times for one's local station (long. **Lo**, lat. **L**) within 200 or 300 miles of a standard station (long. **LoS**, lat. **LS**). Multiply **a** by the difference in longitude (**Lo — LoS**), and multiply **b** by the difference in latitude (**L — LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

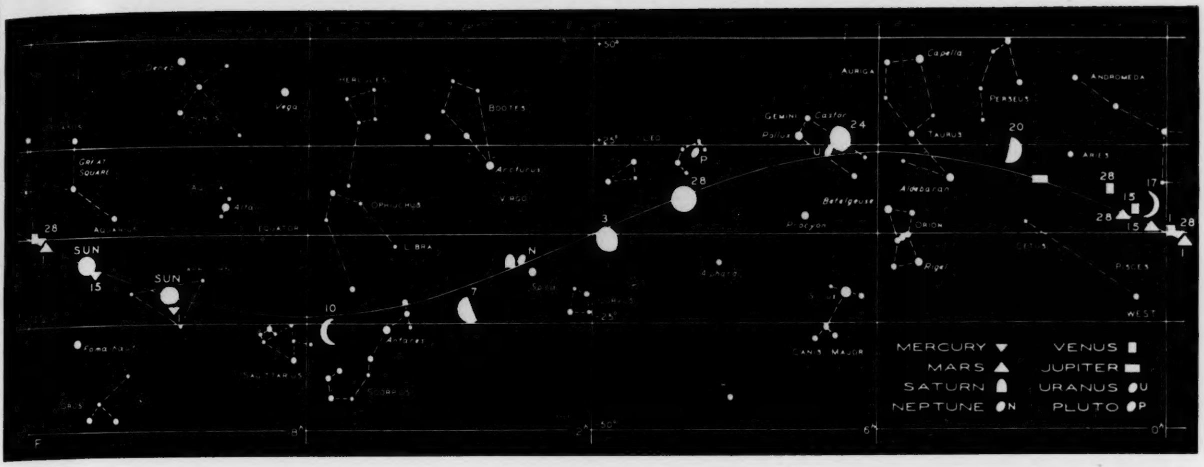
Longitudes and latitudes of standard stations are:

A +72°.5, +42°.5 **E** +91°.0, +40°.0
B +73°.6, +45°.6 **F** +98°.0, +31°.0
C +77°.1, +38°.9 **G** +114°.0, +50°.9
D +79°.4, +43°.7 **H** +120°.0, +36°.0
I +123°.1, +49°.5

MOON PHASES AND DISTANCE

Last quarter	February	7,	4:09
New moon	February	14,	1:10
First quarter	February	20,	17:44
Full moon	February	28,	18:59
Last quarter	March	8,	18:26

	February	Distance	Diameter
Apogee	1, 12^h	252,300 mi.	29′ 25″
Perigee	14, 10^h	221,900 mi.	33′ 28″
Apogee	28, 14^h	252,400 mi.	29′ 24″



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month and for other dates shown.

Sun. A partial eclipse of the sun takes place on February 13-14, invisible in the Western Hemisphere except for Alaska. Maximum obscuration of the sun's diameter will be 76 per cent; the eclipse will be mainly visible in China, Japan, and eastern Siberia.

Mercury becomes an evening star on February 2nd and may be viewed the last week of the month without difficulty. On the 20th, the elusive planet sets one hour after the sun, shining at magnitude —1.0. Greatest elongation occurs on March 2nd, 18° 10′ east of the sun, but by then the brightness will have decreased to —0.2.

Venus appears as the brilliant object in the western sky for nearly four hours after sunset. Greatest eastern elongation was attained on January 31st, and Venus is now moving toward maximum brilliance in March. On the 15th, the planet is at magnitude —4.2. Appearing as a crescent in a telescope, the planet's disk is 43 per cent illuminated and 29″ in diameter, increasing in size as the area of illumination decreases.

Mars, also in the evening sky, is west of Venus and of 2nd magnitude. Mars continues in eastward motion, but will be of little interest for the remainder of the year.

Jupiter, with the above three planets, will be in the western sky in the evening hours. Eastern quadrature with the sun occurs on February 1st. Jupiter, in eastern Aries, sets at midnight on the 15th, and is of magnitude —1.9.

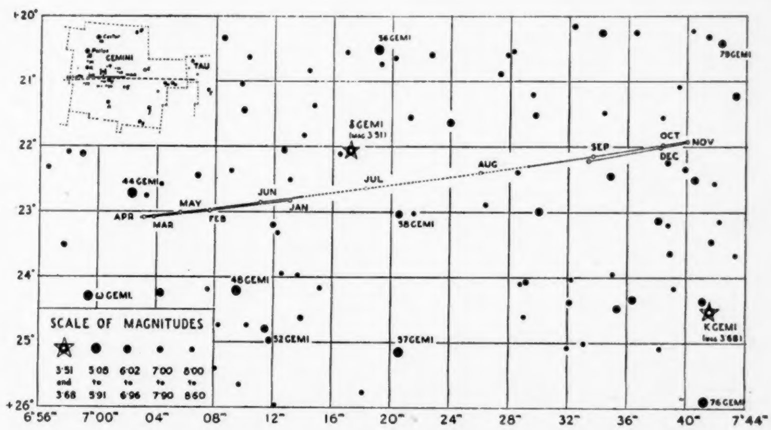
Saturn rises five hours after sunset in mid-February, and is located about 6° northeast of Spica in Virgo. It is at magnitude +0.7 on the 15th, outshining Spica by half a magnitude. Retrograde motion commences on February 6th, preceding Saturn's opposition in April. The ring system appears inclined 14°.5 in mid-month, with the northern face in view.

Uranus will be favorably situated, above the horizon most of the night. It continues westward motion in Gemini, passing about 15′ north of R Geminorum on February 23rd. The variable star is nearing maximum, and observers may see a 6th-magnitude stranger in the field while estimating the star. Uranus' path for the year is shown on the diagram.

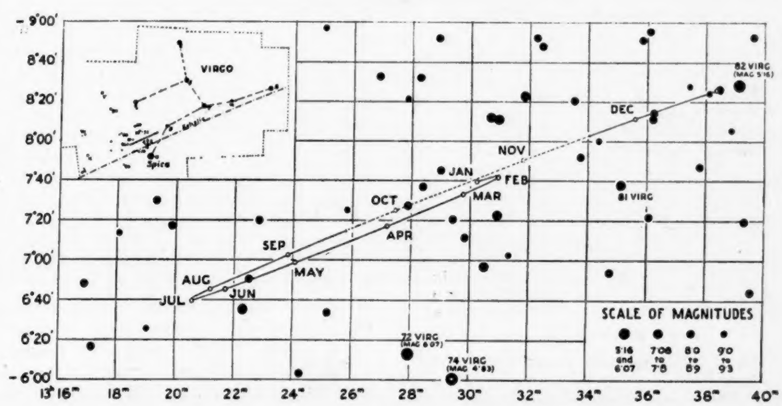
Neptune, located about 4° west of Saturn, is in retrograde motion. Its position on the 15th is 13^h $30^m.5$, —7° 38′ (1953). Its path for the year appears on the special diagram.

Pluto comes to opposition on February 11th, at a distance of 34.6 astronomical units from the earth. It is approximately 3° south of Mu Leonis and 2° southeast of Epsilon Leonis, and is at 9^h 50^m 54^s, +23° 17′.2 (1950 co-ordinates) on the 12th. This faint object may be viewed only in a telescope of at least 12 inches aperture, with the aid of a chart of the region showing stars to the 15th magnitude. Its path among the brighter stars of Leo is shown on the facing page.

E. O.



The path of Uranus among the stars in Gemini is shown above; that for Neptune among the stars in Virgo, below. In each case the field is inverted, with south at the top, as seen in an astronomical inverting telescope. The scale of the charts is not the same. From the 1953 "Handbook" of the British Astronomical Association.



G FORCES AND WEIGHT IN SPACE TRAVEL

(Continued from page 98)

board, you become weightless during the jump because there is no force supporting you. In a quick drop while riding in an elevator you have all experienced, momentarily, the peculiar stomach-lifting sensation which is a result of the relaxation of the tissue which carries the normal weight of the inner organs. The only decisive difference between your own experience and that of the space traveler is that your weightless state lasted only for a very short time — one or two seconds at the most — while the future astronaut will encounter it for longer periods of time.

It is completely unknown what a prolonged state of weightlessness does to the human body. We can rule out any severe disturbances of circulation, but should expect some trouble in orientation and muscular co-ordination. The entire system of reflexes which controls orientation and motion of our body will be upset. It is very likely that the future space pilot will adapt himself to this new environment. He must learn to disregard some information furnished by his senses and to evaluate other information in a different manner. A new set of reflexes must be developed. This is similar to the process one undergoes in learning to ride a bicycle, to drive a car, to fly an airplane, or more especially to fly blind on instruments. The first experience of being in a prolonged state of weightlessness might be disturbing. There might also be some difficulties during sleep, when the mind no longer is alert enough to ward off the deep-rooted sensations of falling, which are associated with the weightless state. But man has a wide range of adaptive abilities, and there is a high probability that he will overcome the eventual difficulties. This will take some time, of course, but just how much is not known. It is necessary, therefore, to gather information on this subject because the weightless period after burnout certainly will be most critical and will require the full efficiency on the part of the crew of the first spaceship ever to leave our planet.

The V-2 rocket is in a state of weightlessness for about four to five minutes. So far this is the longest period of zero weight ever achieved. Some experiments with animals have been carried out by Henry and his coworkers of the Air Force Aeromedical Laboratory at Wright Field, using an Aerobee rocket, which provides a somewhat shorter time of weightlessness. The experiments were designed to prove whether or not any circulatory changes would occur. It was shown that, other than some insignificant changes in the activity of circulation, nothing serious happened. For obvious reasons, no evidence of disturbances in orientation could be obtained from animals. This field must be investigated with human subjects.

It has been often proposed that some artificial gravity be provided by rotating the spaceship and thus producing weight. Such a method, however, is not practical for a spaceship having a restricted diameter. In order to produce the normal weight, the rate of spinning must be appreciably high. Since the center of the ship is the center of rotation, there is no weight in the center. Weight increases rapidly toward the wall. Those marked differences in weight and in circumferential speed over short distances make motion quite difficult. Think of the exceptional case of a man with the axis of rotation passing through his center of gravity. He has the feeling of standing on his head, but having his feet on the ground at the same time. The rotating spaceship, however, has its merits for providing weight if the ship can be made large enough, as in the case of a satellite. Here the speed of rotation can be made smaller and the weight gradient along the radius is no longer a source of trouble.

There are more occasions in rocket and space flight involving variation of weight. For example, there is the famous proposal by Saenger to accelerate a rocket with wings to high speed and high altitudes. After burnout the rocket would return into the denser layers of the atmosphere, where enough lift could be provided by the wings to pull out of the atmosphere again. The method is about the same as that of skipping a flat stone over the surface of water; after touching the water it bounces into the air. By repeating this bounce-and-jump method in a rocket, one can cover surprisingly great distances; depending upon the initial speed, one could fly half way around the earth.

From the foregoing it is clear that no support exists during the coasting period of such a rocket. Therefore, the rocket is without weight during this time. As soon as the rocket enters the atmosphere again, the wings produce lift and, consequently, weight. It is obvious that in such a pullout the weight will be much greater than the normal weight. Therefore, periods of weightlessness will be followed by periods of superweight. It is very likely that for this reason such a trip would not be a pleasure trip. One must pay with superweight for the pleasure of weightlessness. This is not only a simple phrase, but rather a real law of physics.

A body in a motion going straight up and down in the gravitational field of the earth must have an average weight during the time of the motion which is exactly equal to the normal weight. For example, weightlessness lasting 10 seconds must be compensated by an 11-fold weight lasting one second, in order to obtain the normal weight as average. The relations are a little more complicated in a circular motion around the earth, but in principle similar reasoning can be applied, resulting in certain statements concerning the trajectory of Saenger's round-the-world rocket. If it is manned, then for reasons of human tolerance the weight during the pullout should not exceed a certain value. For the purpose of this discussion let's put this value at six times the normal weight. If the first period of weightlessness lasts 15 minutes, then the sixfold weight must last slightly over two minutes. Therefore, this simple law of the average weight can be used to show how periods of subweight must be followed by periods of superweight and how their duration is determined.

The variation of weight will be the strangest among the many new experiences of the future space traveler. Man lives with the weight of his body from the first moment of his life, and weight is so much a part of him that he almost forgets about it. Scientists will work together to supply the spaceship with everything to which a man is accustomed in his daily life. He will have air to breathe, food to eat, the climate will be suitable, the lights should simulate day and night, but there is one thing man must leave behind and that is his weight. This will certainly be the most incisive event in the life of the astronaut when the firm grip of his home planet lets loose. He will then have a similar feeling to that of Christopher Columbus when the coast of Spain sank below the horizon.

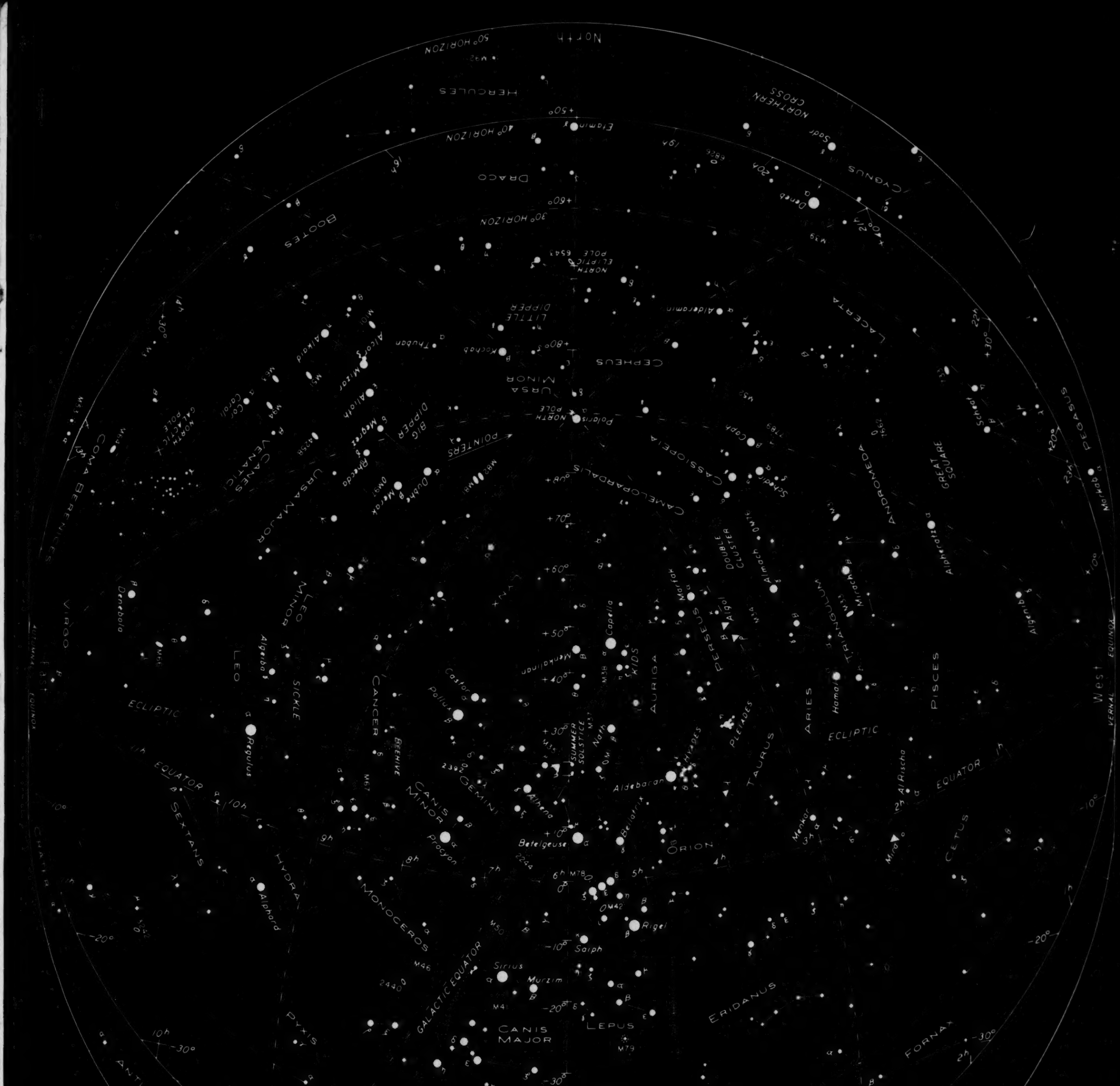
RADIO ASTRONOMY AT JODRELL BANK — I

(Continued from page 96)

crete piles are being driven 60 feet into the ground. These piles support the concrete runway, 320 feet in diameter, to which the railway track is fixed. The total weight of the telescope above ground will be nearly 1,500 tons. The parabolic bowl alone weighs 300 tons; it is 250 feet in diameter, 60 feet deep at the focus, and is carried on trunnions 180 feet above ground level. It will be seen from the artist's drawing that the mounting is altazimuth; nevertheless, electronic control of the metadyne driving motors will enable the instrument to be given almost any type of motion, including automatic sidereal motion for tracking a particular star or region of the sky.

When completed, this radio telescope will be applied to the problems of the radio emissions from space, and in particular to exploration of the regions of the Milky Way which are obscured by interstellar dust. It is also hoped to use it eventually in those problems in radio astronomy requiring the transmission of radio waves. Some of these radio-echo studies of meteors now in progress at Jodrell Bank will be described next month.

(To be concluded)



STARS FOR FEBRUARY

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of February, respectively; also, at 7 p.m. and 6 p.m. on March 7th and 23rd. For other times, add or subtract ½ hour per week. When facing north, hold "North" at the bottom; turn the chart correspondingly for other directions. The projection (stereographic) shows celestial co-ordinates as circles.